REPRODUCTION AND RECRUITMENT OF FISHES IN A HYPEREUTROPHIC SYSTEM (ONONDAGA LAKE, NEW YORK)

By

Mark A. Arrigo

A thesis
submitted in partial fulfillment
of the requirements for the
Master of Science Degree

State University of New York
College of Environmental Science and Forestry
Syracuse, New York
October 1998

Approved:

Faculty of Environmental and Forest Biology

Neil H. Ringler, Major Professor

Neil H. Ringler, Faculty Chair

Lianjun Zhang, Chair, Examining Committee

Robert H. Frey, Dean of Instruction and Graduate Studies

Arrigo, Mark A. Reproduction and recruitment of fishes in hypereutrophic system (Onondaga Lake, New York).

Typed and bound thesis, 122 pages, 21 tables, 30 figures, 1998

ABSTRACT

Reproduction of fishes was studied during 993 and 1994 in hypereutrophic Onondaga Lake, New York. Onondaga Lake currently has levels of contaminants known to cause reproductive abnormalities in fish and a littoral zone that consists primarily of calcium carbonate industrial waste. Annual reproduction is highly variable and spatially limited within the lake. Nesting activity and young-of-year fish populations are mostly limited to the northern half of the lake. Sparse macrophyte growth may limit recruitment of juvenile fishes even in years when initial reproductive success is high. Littoral zone enhancements in the form of spawning structure and substrate, and aquatic vegetation nursery areas significantly increased density of centrarchid nests and juvenile fish abundance. Several large manipulation sites will need to be constructed to significantly influence target species. The results of this thesis provide a reference point for future remediation efforts in Onondaga Lake.

Author's name in full Mark Anthony Arrigo

Candidate for the degree of Master of Science Date 12 /11/98

Major Professor Neil H. Ringler

Faculty Environmental and Forest Biology

State University of New York College of Environmental Science and Forestry, Syracuse, New York

Signature of Major Professor Neil H Ringler

ACKNOWL DGMI NT

v d f k d my h ks my m
p fe D N H. Ri w f h
pport ompl f h pi mi h h im
w d p ly k h k w wi ho wh m h
h wo d h bee m Ch m
di b f m my Ono ag Lake
d pi di y d ly rt m h
T w w y w pi id hi h
h d d m h d fi h wi h. w k
h k h members my mmi D rt W D
ff d M Thom Ch f h m
mm

w d k h k J M k
T y G di J h K Hi h
ch Ch M d M M hy h m y h op
wh h d wi h h f d work. y w k h k
my m h d f h f pi vidi ou m pp
h y

pport w t y h D rtme f
m l and F y Ul h U. m
A cy h Onond Lake Ma em C f
d Wh d O dag County.

TABLE OF CONTENTS

INTRODUCTION AND BACKGROUND

Onondaga Lake is located on the northern border of Syracuse, New York (lat. 43° 06'54", long. 76°14'34"). The lake has a surface area of 11.7 km^2, a volume of 131 x 10^6 m^3, a mean depth of 10.9 m and a maximum depth of 19.5 m (Effler and Hennigan 1996). It is 7.6 km long and has a maximum width of 2 km. The lake empties into the Seneca River via the outlet at the north end. The Seneca River joins the Oneida River to form the Oswego River, which then discharges into southeastern Lake Ontario, approximately 65 km north of Onondaga Lake.

The watershed of Onondaga Lake is 642 km^2 and almost wholly contained within Onondaga County (Effler and Hennigan 1996). The lake is fed by five major and two minor natural tributaries. Ninemile Creek and Onondaga Creek account for about 72% of inflow to the lake. Water from a sewage treatment plant accounts for 17% of the annual flow to the lake, making it the third largest tributary to the lake.

Onondaga Lake was once described as the most polluted lake in the United States (US Senate Committee on Public Works 990). Industrial and metropolitan wastes have entered its waters for over a century. Standards for dissolved oxygen (DO), fecal coliform, ammonia, nitrite, turbidity, and mercury concentration in fish have been routinely violated for many years (Effler and Hennigan 1996). More than 90% of the surface sediments in the lake are contaminated with mercury, resulting in elevated levels in the fish. Fishing in the lake was banned in 195 and reopened in 1986 with a warning to eat no fish from its waters.

Domestic sewage inputs and other non-point nutrient loadings have greatly increased phytoplankton growth, resulting in frequent algal blooms, high turbidity, and extended periods of hypolimnetic anoxia, which during fall turnover, has sometimes resulted in lakewide anoxia. Untreated sewage from combined sewer overflows enters the lake during rain events. The Onondaga County Metropolitan Sewage Treatment Plant (Metro) was originally constructed in 1925 to settle and chlorinate waste. An upgrade of the facility was completed in 1960 that included settling tanks and chemical coagulation. The Metro plant was upgraded to secondary treatment in 1979 and tertiary treatment in 1981. The current tertiary capacity of the plant is 120 million gallons per Effluent is discharged directly to Onondaga Lake. On average, 80 million gallons of sewage effluent enters Onondaga Lake daily waste does not undergo nitrification treatment, resulting in violation of USEPA free ammonia standards for most of the summer months (Effler and Hennigan 1996).

Soda ash manufacturing by a plant originally named the Solvay Process Co. (later part of Allied Signal Co.) used the chloro-alkali process along the shores of the lake starting in the late 1800's and ceasing in 1986. The waste products from this process, calcium carbonate and sodium chloride were discharged directly to the lake until the early 1900's, and later to wastebeds near the lake. Presently these wastebeds surround about 30% of the lake. Wastebeds immediately adjacent to the lake extend into and cover the littoral zone. Historical precipitation of $CaCO_3$ from a super saturated water column has produced a littoral zone that is largely covered with small $CaCO_3$ nodules called oncolites. These nodules resemble gravel but are much less dense and are easily moved about by wave action from winds or boat traffic

From 1946 to 1986 Allied Signal released waste mercury from its facility into Onondaga Lake as a by-product of mercury electrolysis to produce sodium hydroxide, potassium hydroxide and chlorine gas. The load of mercury to the lake during this time has been estimated at 10 kg/d (Effler and Hennigan 1996). USEPA estimated that approximately 75,000 kg of mercury were discharged to Onondaga Lake from 1946 to 1970 (Effler and Hennigan 1996).

The first documented report of the fish community in Onondaga Lake comes from Father Simon LeMoyne who observed Atlantic salmon (Salmo salar) in the lake in 1654 (Beauchamp 1908). Atlantic salmon in the Oswego River drainage, most likely populations that migrated from Lake Ontario, were considered by Webster (1982) to have been "the most striking example of freshwater colonization by Atlantic salmon anywhere in the world." Apparently salmon entered the Oswego River system in June and made their way to Onondaga Lake via the Oswego and Seneca Rivers

(Ringler et al. 1994). It is known that salmon were abundant in the Seneca River and Onondaga Lake as late as the 1870's (Fox 930). A dam built in Baldwinsville appears to have negatively impacted the salmon run above Onondaga Lake by the year 1815 (Clinton 1815). Although the Baldwinsville dam would not have had a direct impact on the salmon fishery in Onondaga Lake, subsequent dams built at Fulton, Mineto, and Oswego would have almost certainly prevented any significant run from reaching the lake

The Onondaga Lake whitefish was fished commercially in Onondaga Lake in the 1800's. It has been assumed that the Onondaga Lake whitefish was a common cisco (Smith 1985). A review of historical literature however, provides some evidence that the Onondaga Lake whitefish was not a common cisco, but may instead have been a another known or unknown species of whitefish or possibly the shortjaw cisco (Coregonus zenithicus). Because the shortjaw has been extirpated from New York waters since the early 1900's, comparative morphological descriptions of the Onondaga Lake whitefish and the shortjaw cisco, are difficult to obtain. One scientific description of the Onondaga lake whitefish that was d d by 0) from im oll d Ono dag L k

d fi d h wh fi h Argyrogomus tullibee,

h no d p h w onc pl d w h

h Argyrogomus y id d h been

m d ifi d p f Coregonus

p id d m m f h pe im h ca y

be rt d pe of d h d he be mp d

m h of h comm d h h w

B d po h m m p bl pec h

id y f h Ononda L k wh fi h I k

b ca h y bo h

w h h p d f b h pe R he d h

beca f l b ow h ra fo h

p bly d h w h comm

h w y d m diblb th of h O daga

L k wh fi h 7 7 d % f da d h p ly

w b w h es h comm nd 8

% f d d h p ly Th body de h f h Onondag

lak wh fi h) ob rved by ea mb th f

shortjaw cisco (19.6-28.6). Common and all other ciscos relatively fusiform fishes with the body depth not exceeding 26% of their standard length. The Onondaga Lake whitefish had a body depth of 28.9% of the standard length, an almost perfect match for the maximum accepted range of the shortjaw (28.6%). In fact, Bean makes special note of the "short, deep and compressed" body of the Onondaga Lake whitefish he examined. Some other descriptions of the whitefish given by Bean are that the head was pointed, the mouth was long and "perch like", the mandible extended to below the middle of the eye and extends slightly, and that the lower jaw scarcely longer than the upper. These characteristics, although difficult to quantify, generally resemble the shortjaw cisco more closely than the common cisco.

Bean reported that no one was ever able to catch an Onondaga Lake whitefish on a hook and line. Shortjaw ciscos are largely planktivores, while it is accepted that common ciscos can be readily caught on minnows (Smith 1985). It is likely that if the Onondaga Lake whitefish were indeed a common cisco that they would have been readily caught on hook and line.

The Onondaga Lake whitefish was commercially fished and considered a delicacy. There are apparently no accounts of common cisco being commercially fished anywhere in New York. The shortjaw on the other hand was known to be commercially fished in Lake Ontario at Oswego in 1875, precisely the same time that the Onondaga lake whitefish was being taken in large numbers in Onondaga Lake. Oswego is just 65 km north of Onondaga Lake and the two are connected via the Seneca and Oswego Rivers. Interestingly, the fishery for shortjaw cisco in Lake Ontario collapsed at precisely the same time as the Onondaga fishery (late 1890's). It could be that the two populations of ciscos were one in the same, traversing the Oswego and Seneca River systems to reach Onondaga Lake much as the Atlantic salmon had.

Finally it appears that the Onondaga whitefish was too large to be a common cisco. The Onondaga Lake whitefish was reported to average about 3 to 4 pounds, whereas the common cisco in New York averages less than a pound, with the state record being only 1-pound 8-ounces. It is unlikely that such large specimens of common cisco d be pl ily O da Lake m: k y h: h

Ono dag Lake wh h w: p p ibly h

h w m d ifi d mm

The y o d f p p f O nda

Lake d h 00 d h pr f d w fi h

mm y h m D d y m h: been

h h p: h hyp m h h h mm

m h: Ri 4 O h p p d h ly

h y f O ond Lake d k o (Acipenser

fulvescens) b rb (Lota lota) d h Am (Anguilla

rostrata

di f h fi h mm y O onda Lake d

ib h: be onduc d. y d

p d pe f fi h

Ono daga Lake Th mb f pe fou d h neca Ri

h: m w ly m h: h k Ri

4 The dy w cond d 4 by

d p d d h l k Ri 4

Fourteen species were captured over a three-day period, but more than 93% of these were carp (Cyprinus carpio). Seining of shallow areas for young of the year fishes resulted in 4 species being captured: log perch (Percina caprodes), sunfishes (Lepomis spp.), white bass (Morone chrysops), and carp (Ringler et al. 1994). A study in 1969 by Noble and Forney (1971) used trap and gill nets to capture 15 species within the lake (Ringler et al. 1994)

In 1981 Tom Chiotti, of the Department of Environmental Conservation, collected and reviewed data from a mercury monitoring program of fish in Onondaga Lake during 1980 and 1981. A total of 22 species were collected using gill nets, trap nets, and seines. White perch was the most abundant species observed (63 %), along with alewife (Alosa pseudodoarengus) 14%). Seining results indicated that several year classes of most fish in the lake were missing. Chiotti (1980) concluded that, with the exception of white perch, reproduction within the confines of Onondaga Lake was "sporadic"

Several changes in the species composition of the occurred between 1946 and 1980. The relative abundance of dramatically decreased and the relative abundance of white perch increased. The decrease in the abundance of carp may reflect improvements in water quality that have allowed other species to colonize the lake, thus relegating the carp to a less significant role within the lake. The abundance of white perch in 1980 is probably due to the natural expansion of that species throughout the region in the 1960's (Ringler et al. 1994). The increase in the number of species captured may be due to the differences in trapping techniques and sampling effort. Tango and Ringler (1990) showed, however, that the increase in species diversity is due partly to improved water quality conditions (Tango and Ringler 1996).

Extensive collections were completed by Ringler et al. (1996) and Gandino (1996) during the late 1980's and early 1990's. These authors found little resemblance of the current fish community to historical accounts. Gandino and Ringler captured 52 species of fishes in Onondaga Lake using trap, gill and seine nets. They found a warmwater fishery dominated by planktivorous fishes (white perch and gizzard shad). Growth rates of most fishes were above the average for New York State waters. Gandino concluded that the rarity of predatory fishes in the lake may be due to lack of reproduction. Reproduction was found to be sporadic and spatially limited within the lake for almost all species.

This thesis is intended to expand upon the work of Ringler and Gandino to give a clearer picture of the reproductive community of Onondaga Lake. Gaps in data and knowledge regarding the reproductive community of Onondaga Lake are identified to give a clearer picture of potential remedial action in the future. The first section of this thesis deals with reproduction and recruitment in Onondaga Lake. Nesting surveys, timing of maturation and lakewide young-of-year population estimates were collected for the first time on Onondaga Lake. Section two explores the potential impacts of water quality on recruitment in Onondaga Lake and in particular the gaps that exist in data collection techniques that would allow for a more thorough investigation. Section three details the fisheries aspects of a littoral zone manipulation project that was jointly conducted by the US Army Corps of Engineers, Rensselaer

Freshwater Institute, New York State Department of Environmental Conservation and the State University of New York College of Environmental Science and Forestry. This project was the first attempt to modify reproductive and nursery habitat in the littoral zone of Onondaga Lake.

OBJECTIVES

The objectives of this thesis were fivefold:

1. To characterize the reproductive community of Onondaga Lake (1993 and 1994);
2. to determine areas of the lake that support nesting;
3. to develop a method to estimate recruitment of young-of-year fishes;
4. to determine if reproductive success can be correlated with water quality; and
5. to determine if manipulation of the littoral zone is a viable remediation tool for Onondaga Lake.

1.0 REPRODUCTION AND RECRUITMENT

1.1 Methods

1.1.1 Nest Surveys

During the spring of 1993 the littoral zone of Onondaga Lake was divided into 51 sections, each approximately 400-m long. The ends of sections were marked near shore with flagged fence posts Nests within each segment were counted once in June from a boat moving along transects by an observer wearing polarized sunglasses. In 1993 the boat was maneuvered in perpendicular transects from shore. The approximate location of each nest was marked on a map of the given segment. No attempt was made that year to identify the species guarding nests.

Several changes were made in **1994 to increase counting** accuracy. Boats were maneuvered along transects parallel to shore. The number of nests for each species observed was recorded for **each segment.** In both years distance between transects was a function of water clarity (closer transects in turbid water); the distance between transects averaged about 10 m. In 1994 some segments were not evaluated due to a lack of appropriate water clarity. Data from the original 51 nest counting sections were combined to form 13 equal sized lake sections to be used depiction and analysis

1.1.2 Timing of Maturation

Adult fish were captured 3-5 times weekly from May 11 to September 7, 1994 using South Dakota trap nets (179 trap nights) and experimental gill nets (35 net nights) at sites used by Ringler et al. (1994) and Gandino (1996). Trap net leaders were perpendicular to shore in water 1 - 3 m deep; wings were set at 45° angles from the trap (Nielson and Johnson 1983). Field crews of two to three people removed fish from the traps daily. Gillnets were fished from May 18 to November 10. Experimental gillnets (50 m in length, with equal length panels of 2.54, 3.81, 5.08, 6.35, 7.62, 8.89 and 10.16 cm stretched mesh) were fished at 1-18 m depths.

A sub-sample of approximately 5 to 10 adults was measured daily (total length in mm) and examined externally to identify state of maturity and sex. Mature fish were considered those yielding eggs or milt under gentle pressure. The fish examined included bluegill (Lepomis macrochirus), pumpkinseed (L. gibbosus), whi perch (Morone americana), gizzard shad (Dorosoma cepedianum), a largemouth bass (Micropterus salmoides).

1.1.3 Recruitment Estimates

Population densities of juveniles were first estimated Onondaga Lake in 1993. Eight sites in 1994 and five sites

0 0 m w m y d with block

f 0 0 mm m h 4 (os w w h

m w h m ba f 0 0 mm m h h from ch w

w pl h ks ifi

co d. A m f d w m (h

mm d w h 0

A m k A m

w nd w k rv from J A us

1994 along with an additional sample completed on September 28. Population estimates of young-of-the-year largemouth bass, sunfish (bluegill and pumpkinseed), white perch, gizzard shad carp (Cyprinus carpio) were calculated using a computer program (Kwak 1992) based on removal models (Seber 1984, Bohlin et al. 1993). Mean numbers of fish in each seine pass from each site were calculated. These sample (pass) means were used to calculate a population estimate and 95% confidence interval for a representative 30 x 20 m area of Onondaga Lakes littoral zone. These estimates and respective confidence intervals (CI) were then extrapolated to lakewide estimates (see example below). Lake density estimates (#/ha) were based on known areas of the study sites (500 m^2), the areas of littoral zone (2.59 km^2), and lake surface (12 km^2). The biomass at each sampling period was calculated from the population estimates and mean mass for each species during each sampling period.

Example: The following procedure was used to calculate population estimates of young-of-year and juvenile fishes in Onondaga Lake. The numbers given are those of young-of-year sunfish in late September 1994. First, the mean of the numbers of individuals captured from each pass at each site is calculated:

Site	First Pass	Second Pass	Third Pass
Bloody Brook	1389	29	509
Crucible Bay	8	9	3
Grandstand	13	1	4
Maple Bay	7	0	4
Marina	5304	247	39
Nine-Mile	49	203	43
Wastebeds	3	1	0
Willow Bay	616	450	257
Total	7389	940	859
Mean	924	118	107

Next, a population estimate, variance and catchability are calculated using the equation from Kwak (1992), where

N= number of fish in population abundance estimate,
$V(N)$= variance of N
k= number of removals,
C_1, C_2 ....C_k = catch in each removal,
T= total catch,
p= catchability,
q= 1-p.
$A = 2C_1 + C_2$

$$N = \frac{6A^2 - 3AT - T^2 + T(T^2 + 6AT - 3A^2)^{0.5}}{18(A-T)}$$

$$V(N) = \frac{N(1-q^k)q^k}{(1-q^k)^2 - (pk)^2 q^k}$$

$$p = \frac{3A - T - (T^2 + 6AT - 3A^2)^{0.5}}{2A}$$

h mpl h p p m w d b

h p h mbe yo f-y fi h 0

0 m f h O d ga L k V

Kw k q w l d be 8 wh h y d

d f b w 0 d fi h y f-y

0 0 m f h O d L k

p pp m ly /47 h k l

one T h m d mb f y f-y

p h k m pl d b h h p im d ppe

d w fid b d by 47 Th d p id d

k w d m f 48 fi h wi h % C f b w

d 7 0 Th mp f h m h d ogy

h h fi h p p m p p y

p f h k w d p p h h k w d

d mm o mi bi h de h

h d f mpl h on w k f h im

d h h p b bi y f pt d d o ei

h m f ch fi h d m f ch p

Mortality rates for young-of-year largemouth bass and gizzard shad in 1994 and largemouth bass between 1993-1994 were calculated utilizing catch curves. The catch curves utilized monthly population estimates as the "catch". This technique assumes equal recruitment and is similar to the cohort analysis method used by Gandino (1996). Catch curves for this study represent the relationship between $\log_e$ of the population estimate versus their age in months from the point at which the population becomes fully vulnerable to the sampling gear (Ricker, 975). Instantaneous mortality (Z) was determined by taking the natural log of the slope of the descending limb of the catch curve. Annual rates of total survival and mortality were calculated from the formula S= (1-A) e^{-Z}

1.1.4 Adult Stock

Fish were captured using the same methods described for timing of maturation. Fish were marked with right pelvic fin clips in the North basin and left pelvic clips in the South basin, or with a combination of a clip and tag for largemouth bass larger than 300 mm. Numbered Floy tags were inserted below the dorsal fin

1.2 Results and Discussion

1.2.1 Nesting Survey

Most members of the families Centrarchidae and Ictaluridae reproduce by building and guarding nests in shallow water during spring and summer. These nests can easily be observed in clear water. Bluegill, pumpkinseed, largemouth bass and rarely brown or yellow bullhead (Ameiurus nebulosus and A. natalis, respectively) have been observed building and/or guarding nests in Onondaga Lake each year from 1991 through 1995. Other members of these families inhabit the lake, but have not been observed spawning. These species include smallmouth bass (M. dolomieu), black white crappie (Pomoxis nigromaculatus and P. annularis, respectively), rock bass (Ambloplites rupestris) and channel catfish (I. punctatus).

A lakewide nest survey was first conducted in 1991, when 1587 nests were encountered (Ringler et al. 1994) (Figure Species guarding nests were not identified and spatial distribution of nests was not described in that early work. The number of nests observed in 1993 was 1277, 77% of which were located in the north basin (Figure -1). A total of 1655 nests were counted in 1994 (Figure 1-2), of which 79% were located in the north basin. Bluegill accounted for 55% of the nests observed in 1994. Unidentified species accounted for 26% of the nests, pumpkinseed 18%, and largemouth bass 1% (Figure 1-4). In 1993 and 1994 the highest densities of nests were located on the northwest shore between Maple Bay and the inlet of Nine Mile Creek. This shoreline is largely composed of oncolitic sediments and is relatively well protected from predominantly northwest winds. The strong relationship (r^2 = 0.922; Figure -5) between the number of nests in each lake section between 1993 and 1994 suggests that some areas may provide better overall conditions for spawning than do other areas of the lake. This relationship may have future management implications. Areas where fish currently nest may be enhanced to provide better spawning habitat; areas where nesting does not currently occur can be enhanced to make the habitat suitable for spawning. Sites to be manipulated should be chosen carefully to avoid areas that will not [illegible] w[illegible] h[illegible] bi[illegible]

[illegible] wh[illegible] may p[illegible]

C[illegible] [illegible] be[illegible]w[illegible]

[illegible] wi[illegible]h [illegible]

[illegible] Th[illegible]

[illegible] Th[illegible]

[illegible] Th[illegible]

[illegible] observed [illegible]

[illegible] northern [illegible]

[illegible] 4 [illegible]

[illegible] of [illegible] may be [illegible]

[illegible] N[illegible]

[illegible]

T m wh m hy

Th h bi h y m h f M y th

rthw f th ik wh h on m f

P h y m fr m O on k

d/ w ffl y w H o k

d th M w T m

Low / fl v m fi h

d y p w on k h

dw H D y m

w o th h M y

Ry th m h fr m May A 4

) M l k m v h th h f

m h w fr m J J y (h y

A dr ws 77 T mm th o m h K hl

Th fi h f m h w rv

on J 4 w m fi l y

f w fl t f o im ly C. Th m h

b 4 ob rv J y Mea

mp O ndag Lake f w h th ferr f

largemouth bass for 16 days, and within an "observed" range for a 25-day period (Sheehan and Sweatman 1993).

1.2.2 Timing of Maturation

Data on sexual maturation were obtained for white perch, bluegill, pumpkinseed, largemouth bass, and gizzard shad in the spring of 1994. Because fewer than 10 mature largemouth bass and gizzard shad were captured, no data are presented for these species. Examined fish were mostly females (71-80%) (Table 1-1). The simplest explanation for the apparent high proportion of females in the population is that the sexes exhibit spatial segregation prior to spawning, and this results in a subsequent differential catch rate in trap nets during the pre-spawn period.

White perch were the first species to be encountered early in the year; mature individuals were observed when sampling began on May 11, 1994. The last sexually mature white perch was captured on June 22, indicating that spawning is most likely completed by this time. The number of mature white perch in the catch peaked in mid

May w mpe be w 4 7 C. m

(1 eport d paw g by wh pe h May an whe

w mp ipp h C. ik ly h wh h

p w g t p ks b w M ly J

Onondag Lak

N imb f m pumpk pe iked J 1 4 ut

h w h f m du o h ne es m ik ds

diff d h A m f m w

p d M y M b l w

J 8 Th mbe m b peaked on J 0 k

mpe b d be wee 7 g 7 M

b w ip d in h k J ly wh

appear d o be w b ed ou m f w

Sep embe o h ik have been known o

h h h imm d um m h 1)

pp h p ik b g p w J wh w

mpe es b b ow 0 Nes in may occur he

f O da L k b h h dit made ifi

b rvati f ly m f m f h imm

1.2.3 Reproduction and Recruitment

A total of 30,313 young-of-year fish (15 species) were captured in Onondaga Lake in 1994 (Table 2). Young-of-the-year white sucker (Castostomus commersoni) and rainbow smelt (Osmerus mordax) captured in the lake were likely derived from lake tributaries since they are stream spawning species. Banded killifish (Fundulus diaphanus), tessellated darter, and emerald shiner reach a maximum size in Onondaga Lake of only about 10 cm as adults; they are difficult to capture and distinguish as young-of-year. Species such as the banded killifish have maintained substantial populations in the lake since 990, yet few young-of-year killifish have been captured in the lake. It is doubtful that enough adult killifish could migrate into the lake to account for the large population observed. This species together with golden shiner (Notemigonus crysoleucas), log perch (Percina caprodes), and brook silversides (Labidesthes sicculus) are considered lake spawners. It is probable that spawning and recruitment of these species occurs within the confines of Onondaga Lake or its limited adjacent wetlands and is responsible for most of the adult population in the lake.

Catch/effort data from 1992 to 1994 show that reproductive success varied widely (Figure 1-9). Reproduction in 1993 was very high after what appears to be an almost complete collapse in 1992; 1994 was a moderately successful year. The proportions of young-of-year between years may be an example of compensatory reproduction. After a very poor reproductive year in 1992 a lack of competition with yearlings could have allowed for increased reproductive success in 1993.

Some reproduction was documented for 12 of the 30 lake-spawning species in the lake in 1994 (40%). Fewer than 10 young-of-year individuals were captured (all sites combined) for 4 of the 2 species (33%) (Table 1-2). Although the overall catch rate for individuals was relatively high in 1994, only 8 of 30 species (27%) known to spawn in lakes experienced significant reproductive success. Some species that are common in the lake as adults, such as northern pike (*Esox lucius*) and walleye (*Stizostedion vitreum*), have rarely been captured as young-of-the-year. Based on the populations observed since the late 1980's (Gandino 1996) these and other species not currently reproducing in the lake have immigrated as adults from the Seneca River and other lake tributaries

Sunfish have dominated the catch of young-of-the-year fishes in Onondaga Lake, accounting for 81%, 59%, and 91% of the total catch in 1992, 1993, and 1994, respectively. While species than sunfish exhibit periodic episodes of high and low recruitment, sunfish exhibit high levels of reproduction in most years. exception to this trend occurred in 1992, when fish reproduction was almost non-existent in Onondaga Lake.

The overall community structure of young-of-year fish populations in Onondaga Lake varies annually (Figure 1-10). The spatial distribution of sunfish and largemouth bass young-of-year appears to be mostly limited to the north basin (Figures 1-11 & 1-12). hypothesized that summer densities of young-of-the-year largemouth bass and sunfish in a particular area of the lake are directly related to spring nest density in that area. However, the stock (nest)-recruitment relationship was not strong (Figure 1-13)

It appears that substantially more annual nest and young-of-year abundance data will be needed to explore this relationship

Population and biomass estimates for five species (gizzard shad, white perch, carp, largemouth bass and sunfish) were calculated for five sampling periods in 1994 and a single sampling period in 1993 and 1995 (Tables 1-3 and 1-4). Gizzard shad, white perch and carp were less numerous in 1994 than in 1993 (32%, 33% and 11% of 993 estimates, respectively) (Figure -14, 1-15, and 1-6). White perch seemed to rebound in 995 (137% of 1993 estimate), while gizzard shad and carp young-of-year abundance remain depressed compared to 1993 (5% and 15% of the 1993 estimate). Reproductive success of sunfish seems to be stable with only minor annual variability observed during the study period (Figure 1-18). Largemouth bass abundance was similar in 1993 and 1995 but much higher in 1994 (Figure 1-17). The higher estimates for largemouth bass in late July 994 (392,767) compared to other time frames (maximum 79,781) is difficult to compare to previous sampling efforts due to the high variability (wide confidence intervals) associated with this sampling period. The annual variability in population estimates, particularly for gizzard shad, white perch and carp, is most likely due to natural fluctuations in reproductive success. Reproductive success of any species is a complex process controlled by many biotic and abiotic variables. Abundance of food resources, predation, climatic conditions, habitat quality, and anthropogenic influences all play a role in the level of reproductive success. Anthropogenic variables and their potential impacts to the reproductive process fishes in Onondaga Lake are discussed in Part 2 of this thesis. Table 1-5 and 1-6 list biomass estimates for the same time periods as population estimates.

White perch population estimates in 994 increased as the season progressed. Gizzard shad population estimates in that same year started high in late July then drop in mid August, only to increase again in September. Temporal fluctuations in catches of these pelagic species may result from movement in and out of the littoral zone between sampling periods; such movement likely biases the estimates of these species. It is likely that the littoral reduction method for estimating population sizes is not valid for species that are at least partly pelagic.

Figure 1-19 depicts estimates of one-year-old largemouth bass in 994 and 1995. These estimates are probably a better indicator of true recruitment to the population than are young-of-year estimates because winter mortality has likely reduced the cohort size. Estimation of one-year-olds of other species was not possible due to low catch rates (gizzard shad, white perch and carp) or the difficulty in identifying the species of one-year-old fish in the field (sunfish). Abundance of one-year-old largemouth bass in July 1994 and June 1995 were almost identical, 10,396 and 0,291 respectively. Young-of-year from 993 were 2.6 times fewer in number than the 994 young-of-year for a comparable sampling period (August of each year) and almost 13 times fewer than their peak abundance in 1994. Yet, the estimated number of individuals recruited to the population (one year olds) was almost identical in both years. Instantaneous rates of mortality (Z) of 1994 young-of-year largemouth bass estimated from cohort analysis of catch curves was 0.64. Although there are too few data to calculate mortality of 993 young-of-year during the summer, it is possible to calculate the winter mortality rate which encompass the time frame from the early fall when the year class is still considered young-of-year to the following spring when the individuals within the cohort are considered to be yearlings (Table 1-7) Mean instantaneous rate of mortality (Z) for bass between 1993 and 1994 was 0.04. Instantaneous rates of mortality (Z) for bass between 1994 and 1995 was 0.11. Mortality for 995 yearlings averaged 2.7 times higher than for 1994 yearlings. This higher mortality, in the 995 yearlings, seems to ameliorate the higher level of reproduction shown by this year class in 1994. Although only two years of data are available, it may be that Onondaga Lake was only capable of supporting a maximum of about 0,000 one-year-old bass in 1993 and 1994. In years where high reproduction produces many more than 10,000 young-of-year, density dependent mortality, e.g. from higher predation rates, may cull the population so that only about 10,000 individuals survive to age one. In years where young-of-year populations are near 10,000 mortality may be very low. The best explanation for this relationship is that habitat within the lake is limiting recruitment. A lack of nursery habitat (usually in the form of macrophyte beds) could cause young-of-year to crowd available habitat, thus competing for food and space, and increasing the possibility of mortality due to predation. This is in essence the mechanism of density dependent mortality. It is likely that f nursery habitat were increased within the lake, bass recruitment would increase; this topic is discussed further at the end of Section 3 of this thesis.

Growth rates of young-of-year largemouth bass in Onondaga Lake appear to be higher than the New York State mean (Table 1-8). This is probably attributable to the early size (60 -69 mm) at which bass switch from a diet dominated by zooplankton to one dominated by fish (Figure. 1-20). Bettoli et al. (1992) found that initiation of piscivory at smaller sizes can enhance first-year growth; those authors also found that, in a lake with submerged macrophyte cover, 39 - 44% of the young-of-the-year bass did not switch to piscivory until reaching a length of 140 mm, probably due to the difficulty in locating and capturing prey. After vegetation was eliminated fish were the predominant prey item consumed by bass 60 mm and longer. The estimated vegetation coverage in Onondaga Lake is only about 14% of the littoral zone (Madsen et al. 1993). This may facilitate the switch from zooplankton to fish in young-of-year bass in Onondaga Lake earlier than in most New York water bodies, thus explaining the high growth rates observed. The relatively high growth rates of bass may also reflect low density and therefore low competition in Onondaga Lake in some years.

1.2.4 Adult Stock

A total of 7145 adult fish (37 species) was collected in trap nets (Table 1-9) and 851 fish (17 species) were collected in gill nets in 1994 (Table 1-9). White perch (53%) were the most abundant species in the lake. The species composition and relative catch rates vary between the gear types due to differences in gear efficiencies among species and different habitats sampled.

Tango and Ringler (1996) calculated that the number of fish species in Onondaga Lake has increased at a steady rate of 0.5-3.3/decade, based on samples rarefied to 164 individuals/year. In most years at least a few species are caught that have not previously been recorded, or have not been seen in decades. New species in 1994 included the fallfish (*Semotilus corporalis*) northern hogsucker (*Hypentelium nigricans*), and troutperch

(Percopsis omiscomaycus). As indicated earlier, connections with adjacent waterways play an important role in maintaining the diversity of the Onondaga Lake adult fish community. These species were represented by a single individual each and are believed to have immigrated into the lake from the Seneca River and lake tributaries. An Atlantic salmon (Salmo salar) smolt was also captured in June, evidently having migrated from Nine Mile Creek (Chris Millard and Neil Ringler, per. comm.). Brown trout (Salmo trutta) and rainbow trout (Oncorhyncus mykiss) were collected in gill nets; fin clips on the rainbow trout indicate that they had been stocked in the Finger Lakes (L. Wedge, NYDEC, pers. comm.).

Table 1-1. Number and percent contribution of mature bluegill (Bg)(N=324), pumpkinseed (Ps)(N=107), and white perch (Wp)(N=242) sampled with trap and gill nets in Onondaga Lake in 1994.

	Bg Females	Bg Males	Ps Females	Ps Males	Wp Females	Wp Males
# Captured	248	76	**86**	21	171	71
Percent	77	24	80	21	71	29

Table 1-2. Species, life history stage, and total number of fish captured by seine in the littoral zone seines in Onondaga Lake in 1994.

Adults		Juveniles (one-year-old)		Young of the Year	
Species	# Captured	Species	# Captured	Species	# Captured
Banded Killifish	1050	Pumpkinseed	1385	Sunfish [1]	27,635
Log Perch	337	Bluegill	158	Gizzard Shad	1207
Yellow Perch	111	Yellow Perch	97	Largemouth Bass	945
Brook Silversides	110	Largemouth Bass	38	White Perch	190
Pumpkinseed	84	Whit Perch	9	Golden Shiner	115
Bluegill	58	Carp	6	Carp	103
Golden Shiner	38	White Sucker	5	Smallmouth Bass	72
Carp	25	Redhorse Sucker	4	White Sucker[2]	21
Fathead Minnow	12	Black Crappie	1	Brook Silversides	12
Largemouth Bass	8	Hog Sucker	1	Alewife	8
Emerald Shiner	5	Smallmouth Bass	1	Brown Bullhead	2
Tessellated Darter	5			Longnose Gar	1
White Perch	5			Rock Bass	1
Spottail Shiner	2			Rainbow Smelt[2]	1
Bluntnose Minnow	1				
Central Mudminnow	1				
Total	1852	Total	1705	Total	30,313

[1] Because of difficulties in identifying young-of-year bluegill and pumpkinseed these two species are combined and called sunfish.

[2] Stream spawning species.

Table 1-3. Population estimates for Onondaga Lake young-of-year fishes during five sampling periods in 1994 and one sampling period in 1993 and 1995.

Species	Sampling Period	Lakewide Population Estimate	95% Confidence Interval
Sunfish	Mid Aug. '93	6,552,415	339,895 - 12,764,935
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	464,995	0 - 1,836,376
	Mid Aug. '94	6,755,408	0 - 14,200,046
	Late Sept. '94	5,513,848	3,823,816 - 7,203,879
	Mid July '95	4,158,990	1,463,436 - 6,854,544
Largemouth Bass	Mid Aug. '93	30,685	944 - 60,426
	Mid June '94	0	0
	Early July '94	66,468	0 - 429,589
	Late July '94	392,767	0 - 2,006,323
	Mid Aug. '94	79,781	23,604 - 136,902
	Late Sept. '94	20,582	330 - 41,071
	Mid July '95	35,783	0 - 147,052
Gizzard Shad	Mid Aug. '93	1,288,767	1,175,469 - 1,402,066
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	405,985	396,543 - 415,427
	Mid Aug. '94	10,386	0 - 21,243
	Late Sept. '94	84,974	80,253 - 89,694
	Mid July '95	69,300	0 - 884,198
White Perch	Mid Aug. '93	221,876	155,785 - 287,966
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	1180	0 - 4,720
	Mid Aug. '94	4721	0 - 11,802
	Late Sept. '94	75,532	68,923 - 82,141
	Mid July '95	303,072	203,465 - 402,681
Carp	Mid Aug. '93	472,548	301,184 - 643,912
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	27,852	0 - 149,176
	Mid Aug. '94	51,456	0 - 101,496
	Late Sept. '94	0	0
	Mid July '95	69,300	0 - 884,198

Table 1 - 4 Population densities of young-of-year in the littoral zone of Onondaga Lake during five sampling periods in 1994 and one sampling period in 1993 and 1995.

Species	Sampling Period	Littoral Zone Population Estimates (#/ha)	95% Confidence Interval
Sunfish	Mid Aug. '93	25,882	1343-50,421
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	1837	0-7254
	Mid Aug. '94	26,684	0-56,090
	Late Sept. '94	21,780	15,104-28,455
	Mid July '95	16,428	5781-27,075
Largemouth Bass	Mid Aug. '93	121	4-239
	Mid June '94	0	0
	Early July '94	263	0-1697
	Late July '94	1551	0-7925
	Mid Aug. '94	315	93-541
	Late Sept. '94	81	1-162
	Mid July '95	141	0-581
Gizzard Shad	Mid Aug. '93	5091	4643-5538
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	1604	1566-1640
	Mid Aug. '94	41	0-84
	Late Sept. '94	336	317-354
	Mid July '95	274	0-3493
White Perch	Mid Aug. '93	876	615-1137
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	5	0-19
	Mid Aug. '94	19	0-47
	Late Sept. '94	298	272-324
	Mid July '95	1197	804-1591
Carp	Mid Aug. '93	1867	1190-2543
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	110	0-589
	Mid Aug. '94	203	0-401
	Late Sept. '94	0	0
	Mid July '95	274	0-3493

Table 1-5. Biomass estimates for Onondaga Lake young-of-year during five sampling periods for 1994 and one sampling period for 1993.

Species	Sampling Period	Lakewide Biomass Estimate (kg)	95% Confidence Interval
Sunfish	Mid Aug. '93	5117	265-9969
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	147	0-582
	Mid Aug. '94	4607	0-9684
	Late Sept. '94	4306	4436-8356
Largemouth Bass	Mid Aug. '93	188	6-370
	Mid June '94	0	0
	Early July '94	48	0-311
	Late July '94	864	0-4414
	Mid Aug. '94	463	137-794
	Late Sept. '94	196	3-391
Gizzard Shad	Mid Aug. '93	11998	10,944-13,053
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	686	670-702
	Mid Aug. '94	22	0-46
	Late Sept. '94	1360	1284-1435
White Perch	Mid Aug. '93	510	358-662
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	1	0-4
	Mid Aug. '94	14	0-35
	Late Sept. '94	302	276-329
Carp	Mid Aug. '93	2694	1717-3670
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	47	0-249
	Mid Aug. '94	216	0-426
	Late Sept. '94	0	0

Table 1-6. Biomass estimates for young-of-year in the littoral zone of Onondaga Lake during five sampling periods for 1994 and one sampling period for 1993.

Species	Sampling Period	Littoral Zone Biomass Estimate kg/ha	95% Confidence Interval
Sunfish	Mid Aug. '93	20	1-39
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	1	0-2
	Mid Aug. '94	18	0-38
	Late Sept. '94	25	18-33
Largemouth Bass	Mid Aug. '93	1	0-1
	Mid June '94	0	0
	Early July '94	0	0-1
	Late July '94	3	0-17
	Mid Aug. '94	2	1-3
	Late Sept. '94	1	0-2
Gizzard Shad	Mid Aug. '93	47	43-52
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	3	3-3
	Mid Aug. '94	0	0
	Late Sept. '94	5	5-6
White Perch	Mid Aug. '93	2	1-3
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	0	0
	Mid Aug. '94	0	0
	Late Sept. '94	1	0-2
Carp	Mid Aug. '93	11	7-14
	Mid June '94	0	0
	Early July '94	0	0
	Late July '94	0	0
	Mid Aug. '94	1	0-2
	Late Sept. '94	0	0

Table 1-7. Instantaneous mortality, annual mortality and survivorship rates of young-of-year largemouth bass and gizzard shad calculated from cohort analysis of catch curves, Onondaga Lake 1993 to 1995.

Species and Time Frame	Z	S	A
Largemouth Bass 1994 YOY	0.64	0.53	0.47
Largemouth Bass 1993 YOY - 1994 1+	0.04	0.96	0.04
Largemouth Bass 1994 YOY - 1995 1+	0.11	0.90	0.10
Gizzard Shad 1994 YOY	0.34	0.71	0.29

Table 1-8. Mean length of 1+ largemouth bass from New York. Data from NE Division AFS Warmwater Workshop, 1993.

Location	Mean Length of One Year Old Largemouth Bass (mm)
Lake Peekskill, NY	209
Lake Erie, NY	198
Hudson River, NY	150
Onondaga Lake (1995)	142
Onondaga Lake (1994)	139
Cayuta Lake, NY	135
New York Mean	126
Seneca River, NY	115
Long Pond, NY	112
Friends Lake, NY	86
Tully Lake, NY	78

Table 1-9 Trap net results for 179 trap nights (May 20 to October 12), Onondaga Lake 1994.

Species	Catch	CPUE
1. White Perch	3821	21.35
2. Bluegill	1291	7.21
3. Pumpkinseed	927	5.18
4. Brown Bullhead	243	1.36
5. White Sucker	103	0.58
6. Yellow Perch	96	0.54
Channel Catfish	94	0.53
8. Bowfin	91	0.51
9. Common Carp	73	0.41
10. Golden Shiner	59	0.33
11. Gizzard Shad	59	0.33
12. Black Crappie	50	0.28
13. Yellow Perch	39	0.22
14. Largemouth Bass	36	0.20
15. Freshwater Drum	33	0.18
16. Smallmouth Bass	33	0.18
17. Shorthead Redhorse	20	0.11
18. Walleye	17	0.10
19. Banded Killifish	10	0.06
20. Emerald Shiner	9	0.05
21. Alewife	7	0.04
22. Rock Bass	5	0.03
23. Fathead Minnow	5	0.03
24. Northern Pike	4	0.02
25. Central Mudminnow	3	0.02
26. Rudd	3	0.02
27. Longnose Gar	3	0.02
28. Rainbow Smelt	2	0.01
29. Creek Chub	1	0.01
30. Tiger Muskellunge	1	0.01
31. Atlantic Salmon	1	0.01
32. Logperch	1	0.01
33. Fallfish	1	0.01
35. Chain Pickerel	1	0.01
36. Northern Hog Sucker	1	0.01
37. Trout Perch	1	0.01
TOTAL	7145	

Table 1-10. Gill net catch for 35 net nights (May 20 to October 12), Onondaga Lake 1994.

Species	Catch	CPUE
White Perch	508	14.51
Gizzard Shad	175	5.00
Yellow Perch	42	1.20
White Sucker	36	1.03
Walleye	19	0.53
Channel Catfish	17	0.49
Shorthead Redhorse	10	0.29
Northern Pike	9	0.26
Common Carp	8	0.23
Pumpkinseed	7	0.20
Smallmouth Bass	5	0.14
Brown Trout	4	0.11
Golden Shiner	4	0.11
Bluegill	2	0.06
Rainbow Trout	2	0.06
Alewife	2	0.06
Largemouth Bass	1	0.03
Total	851	24.31

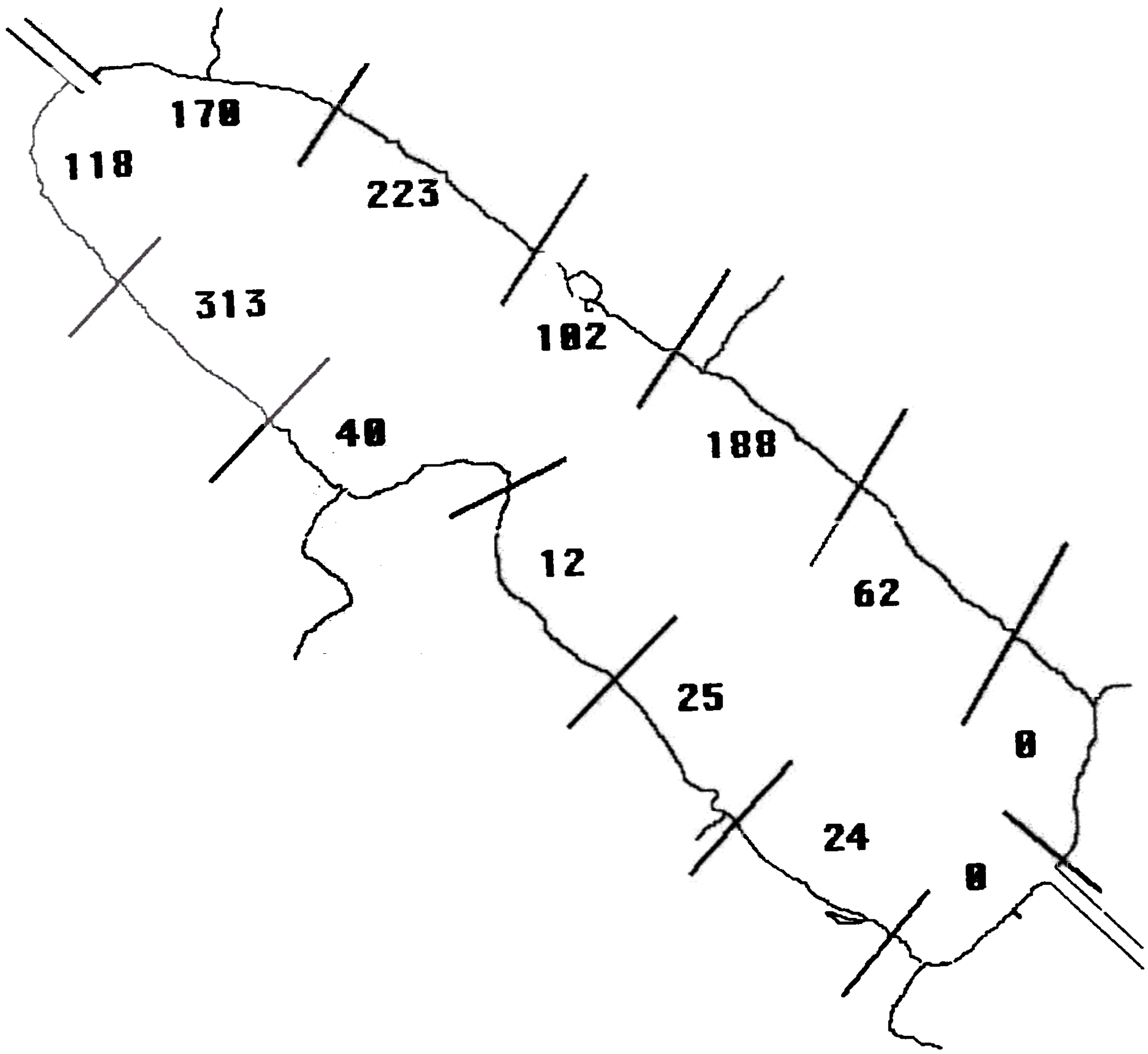


Figure 1-1. Number of fish nests observed in 13 compartments of equal shore length in Onondaga Lake, June 1993.

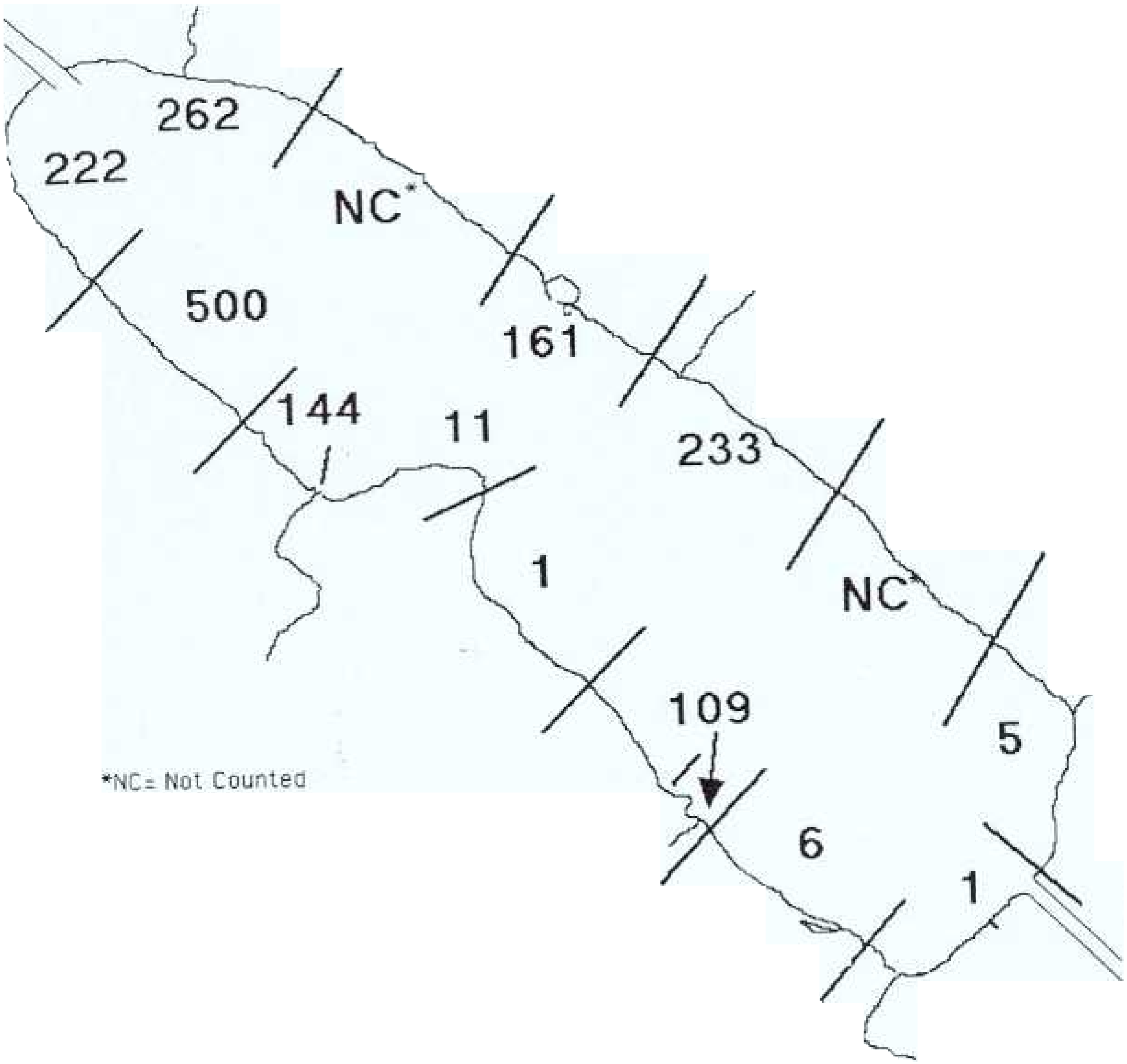


Figure 1-2. Number of fish nests observed in 13 compartments of equal shore length in Onondaga Lake, June 1994.

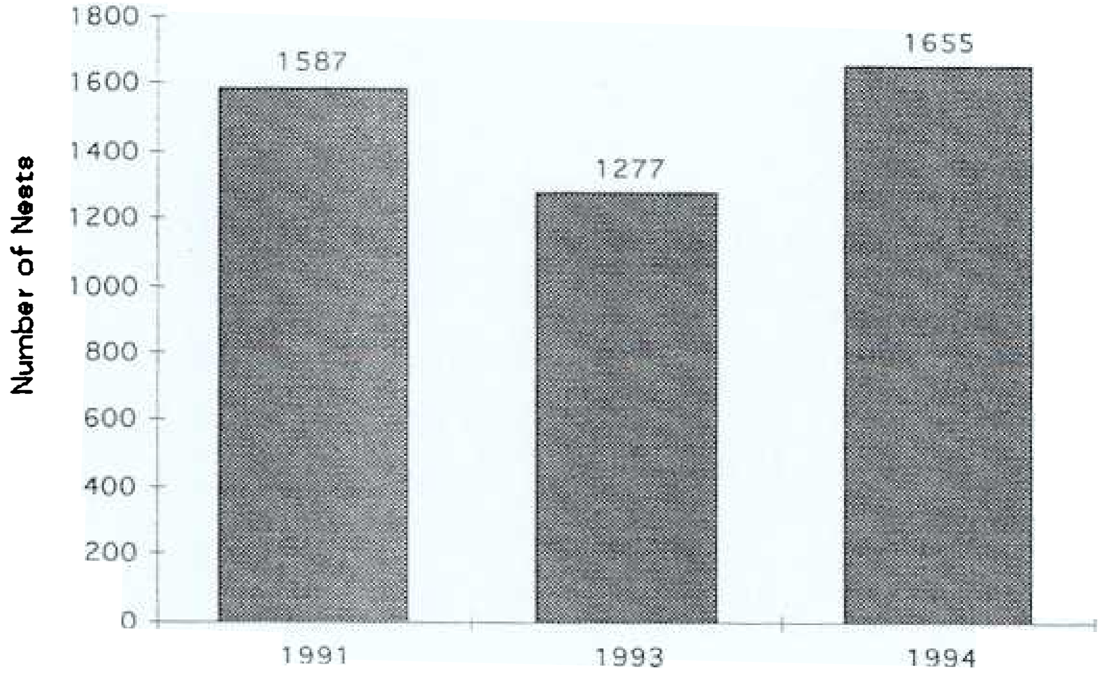


Figure 1-3. Total number of fish nests observed in surveys of Onondaga Lake in 1991, 1993, and 1994.

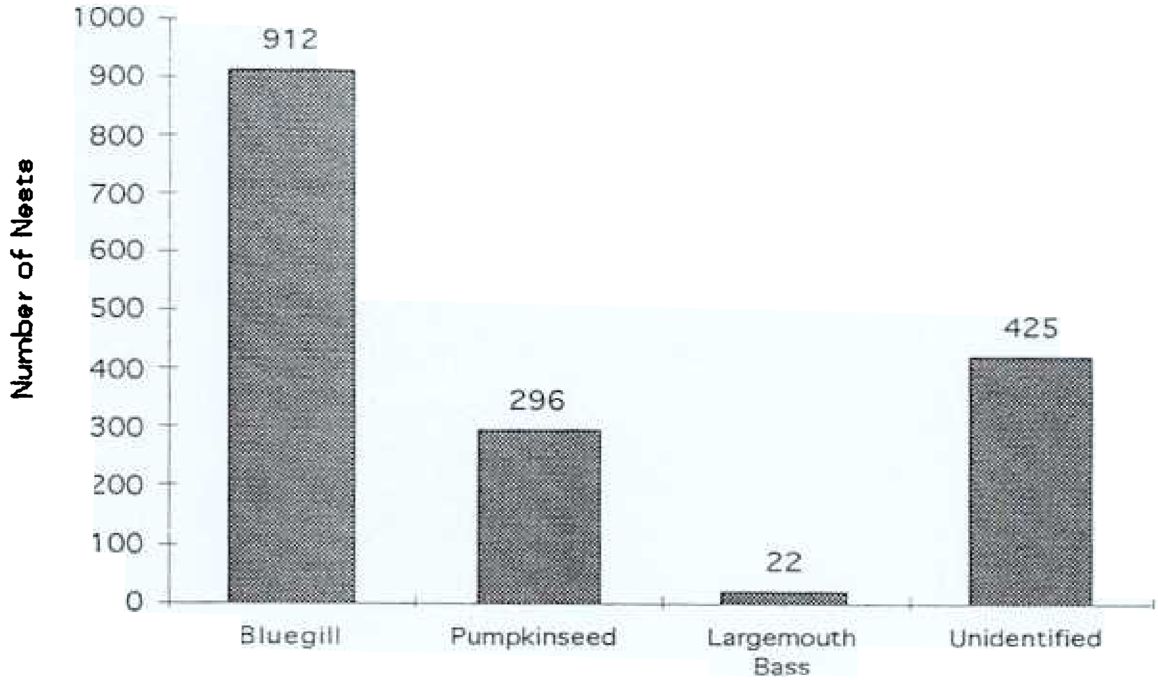


Figure 1-4. Total number of bluegill, pumpkinseed, largemouth bass, and unidentified nests observed during an Onondaga Lake nesting survey in 1994.

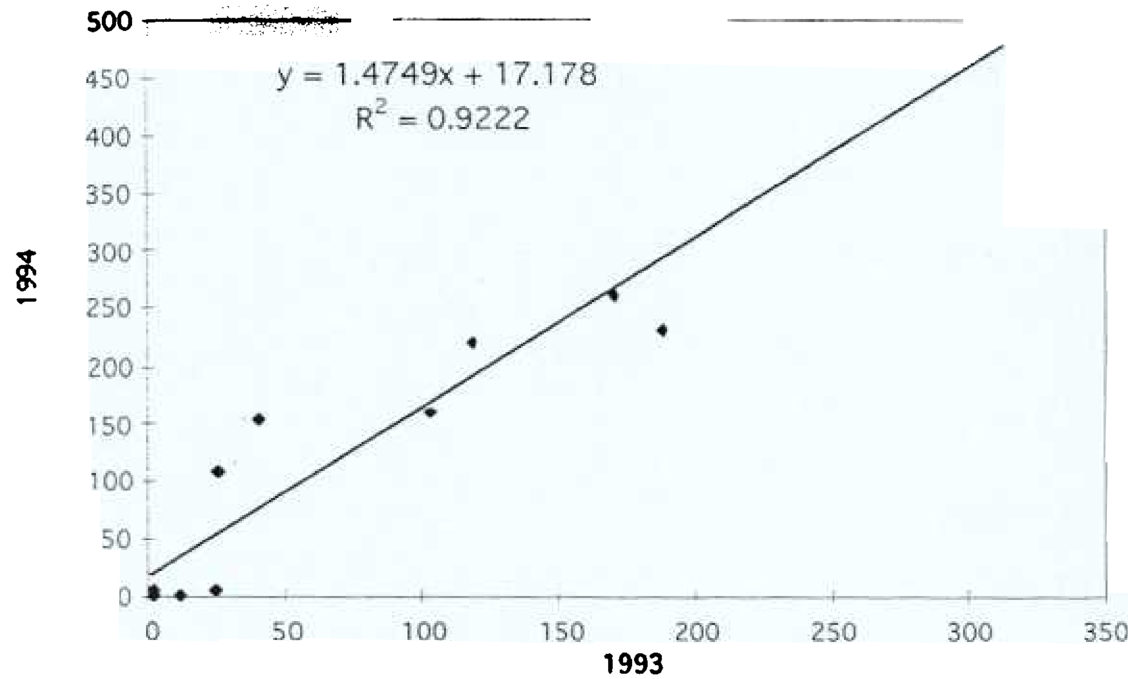


Figure 1-5. Linear regression of the number of observed nests by lake compartment in 1993 and 1994

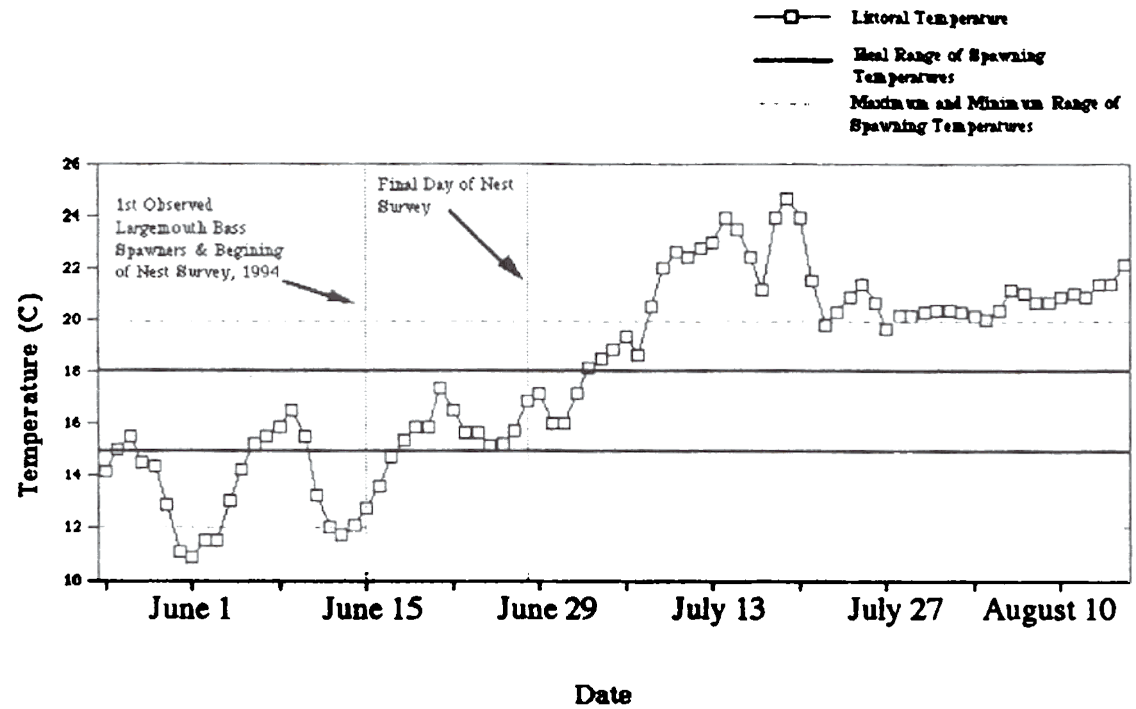


Figure 1-6. Comparison of mean littoral zone water temperature (C), with known spawning temperature preferences of largemouth bass in 1994.

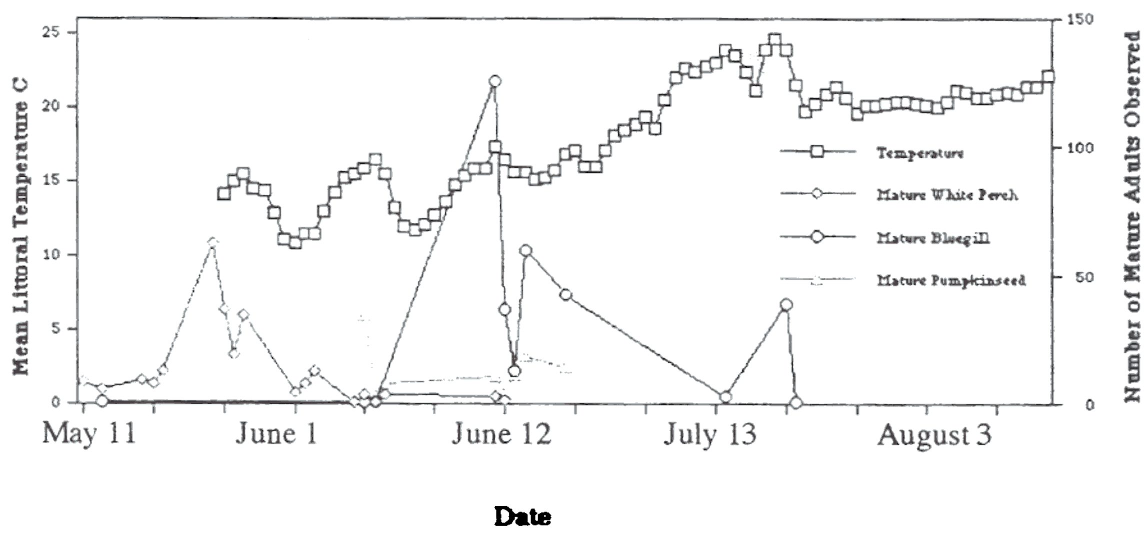


Figure 1-7. Comparison of the number of captured mature bluegill, pumpkinseed and white perch adults and littoral zone temperature in 1994.

Figure 1-8. Location of seine collections in 1993 (5 sites) and 1994 (8 sites) on Onondaga Lake.

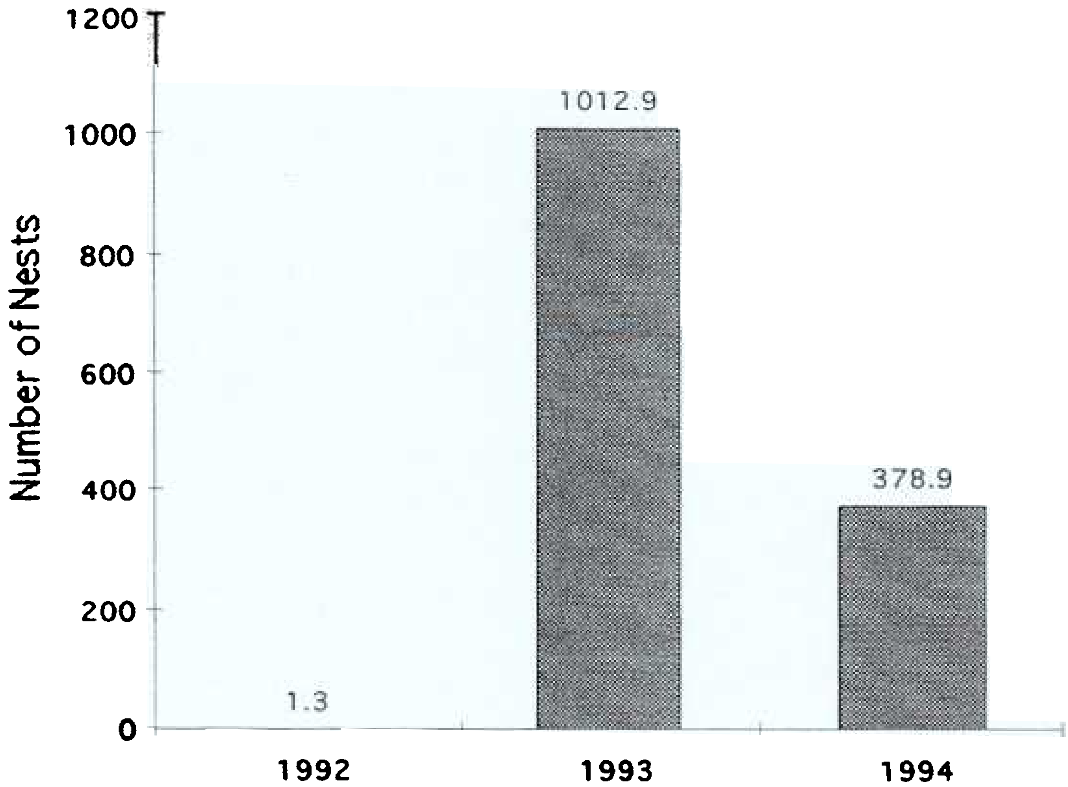


Figure 1-9. Catch per unit effort (CPUE) in seine hauls of young-of-year fish from Onondaga Lake in 1992, 1993 and 1994 (error bars are standard deviation).

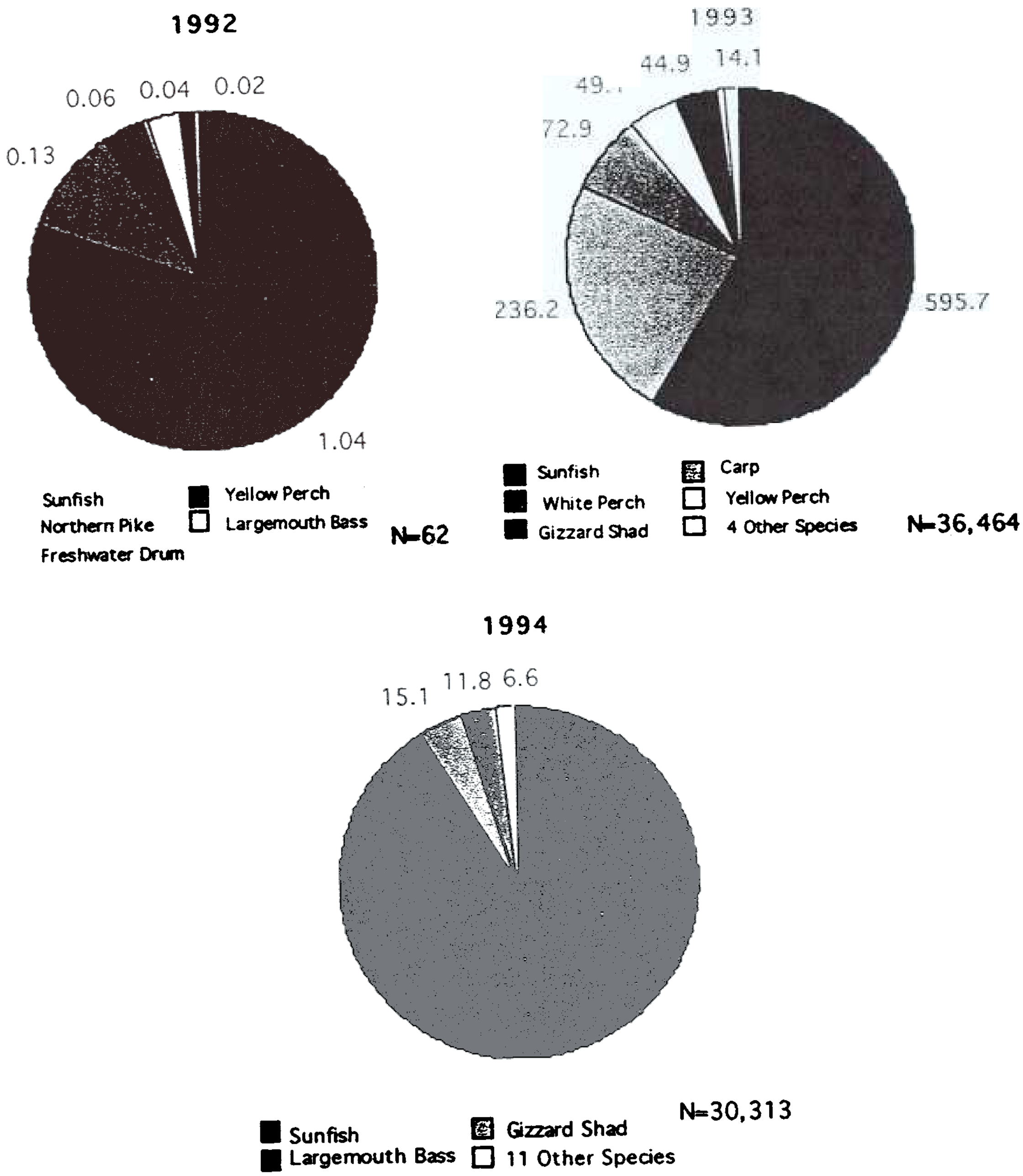


Figure 1-10. Community structure (catch per unit effort) of young-of-year fishes in Onondaga Lake in 1992 (48 seine hauls), 1993 (36 seine hauls), and 1994 (80 seine hauls).

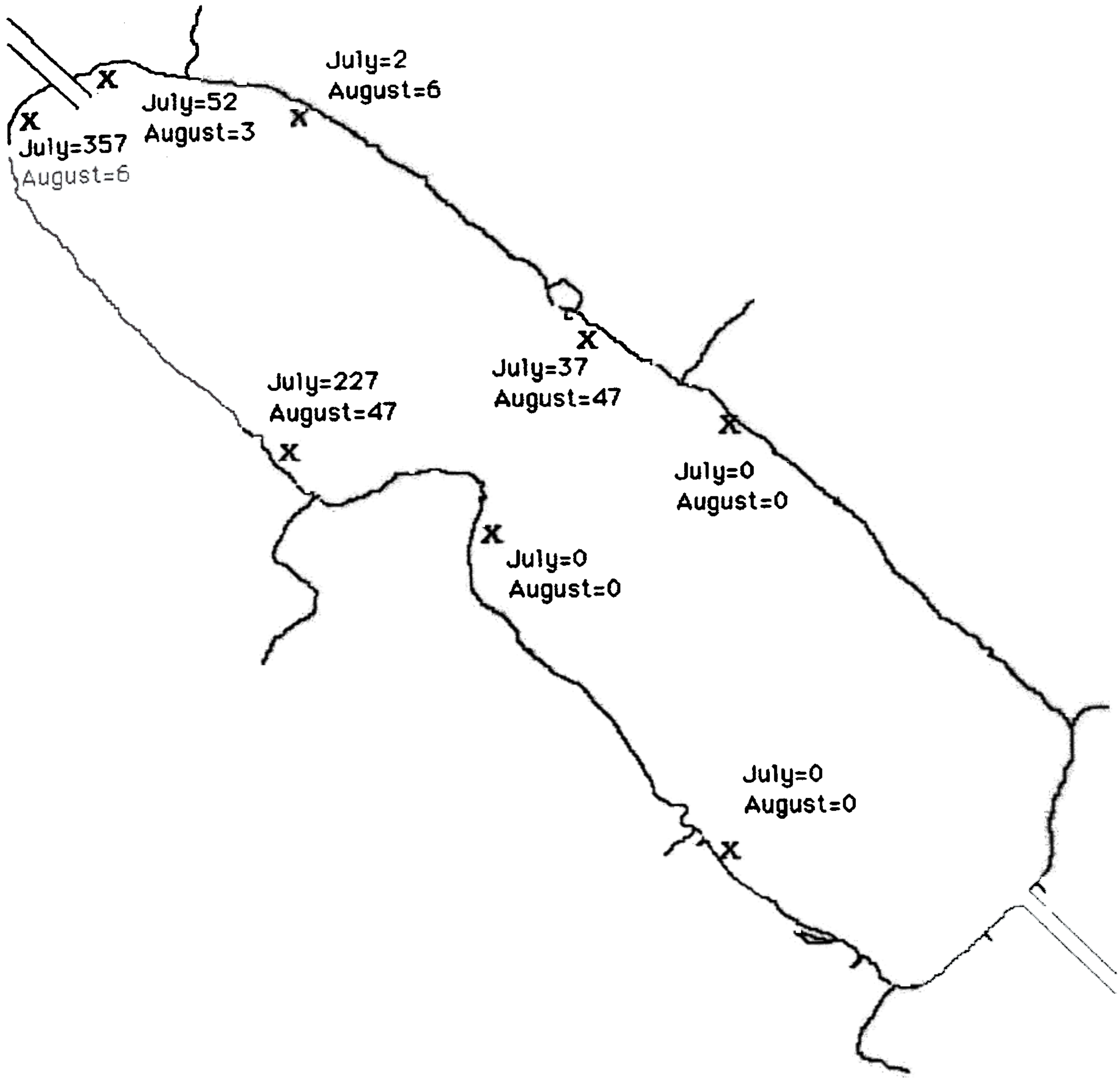
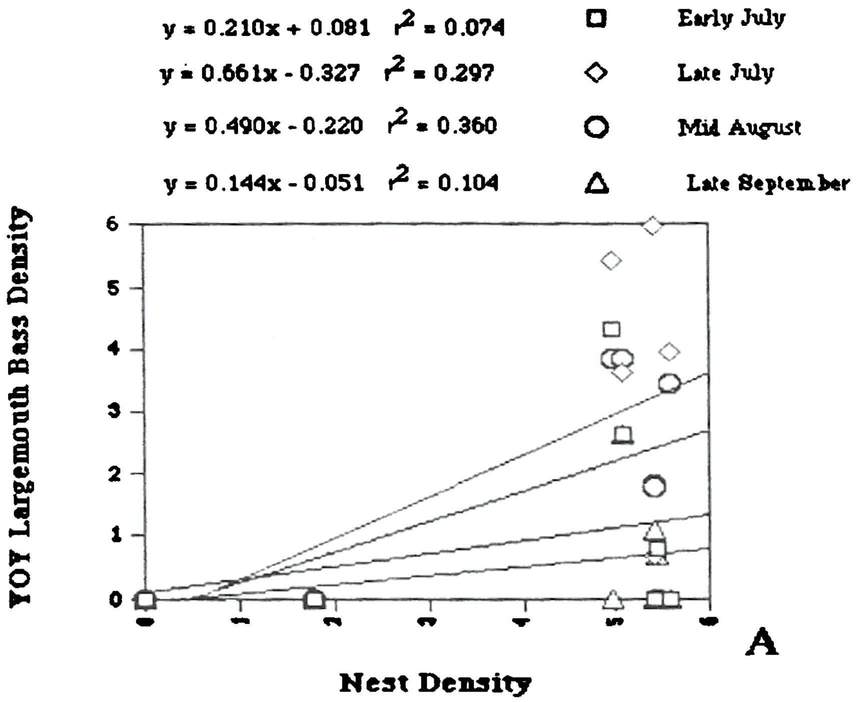


Figure 1-11. Estimated numbers of young-of-year largemouth bass at each sampling site in Onondaga Lake in late July and mid August 1994.

Figure 1-12. Estimated numbers of young-of-year sunfish at each sampling site in Onondaga lake, late July and mid August 1994.



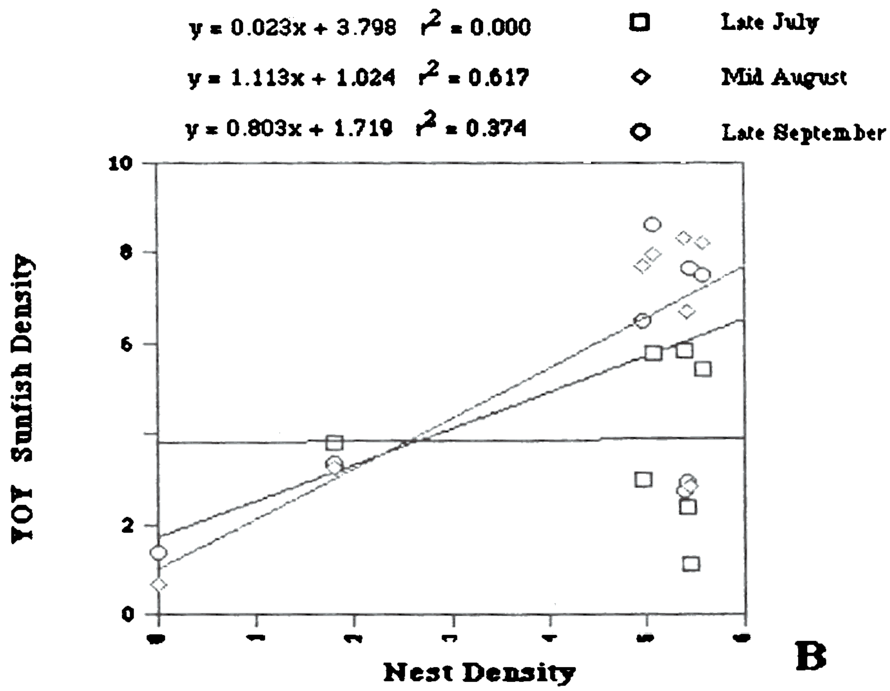


Figure 1-13. Linear regression of the nest density within individual lake sections and subsequent young-of-year density of largemouth bass (A) and sunfish (B) within those sections at different time periods in 1994.

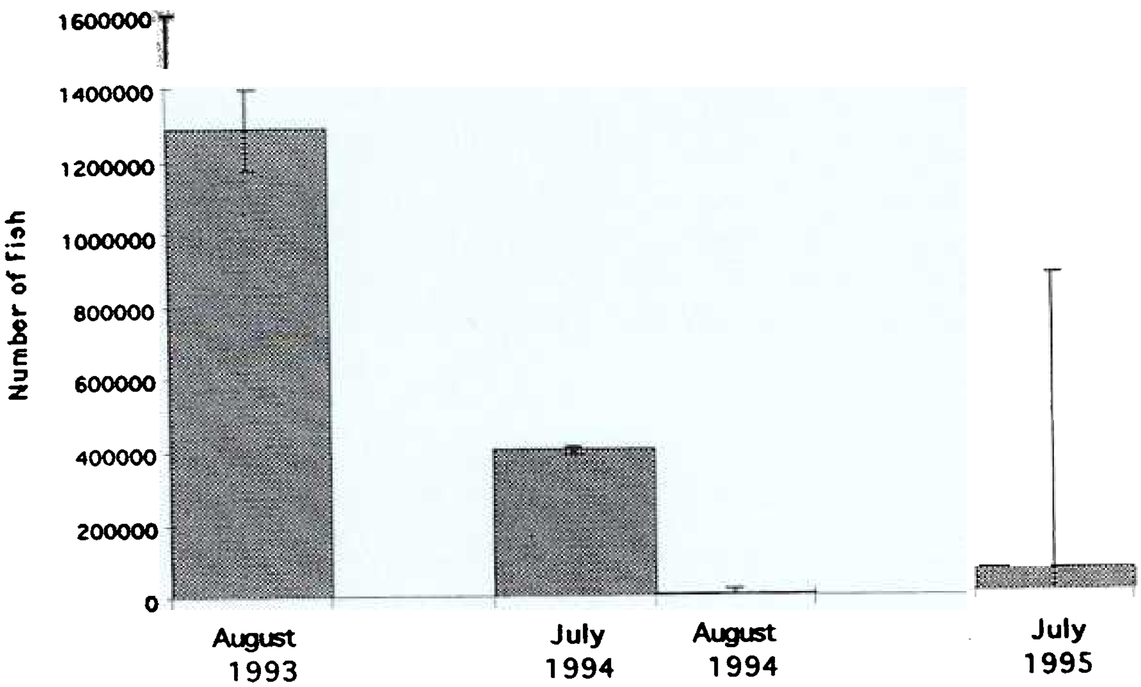


Figure 1-14 Population estimates of young-of-year gizzard shad and 95% confidence interval in Onondaga Lake in 1993, 1994 and 1995.

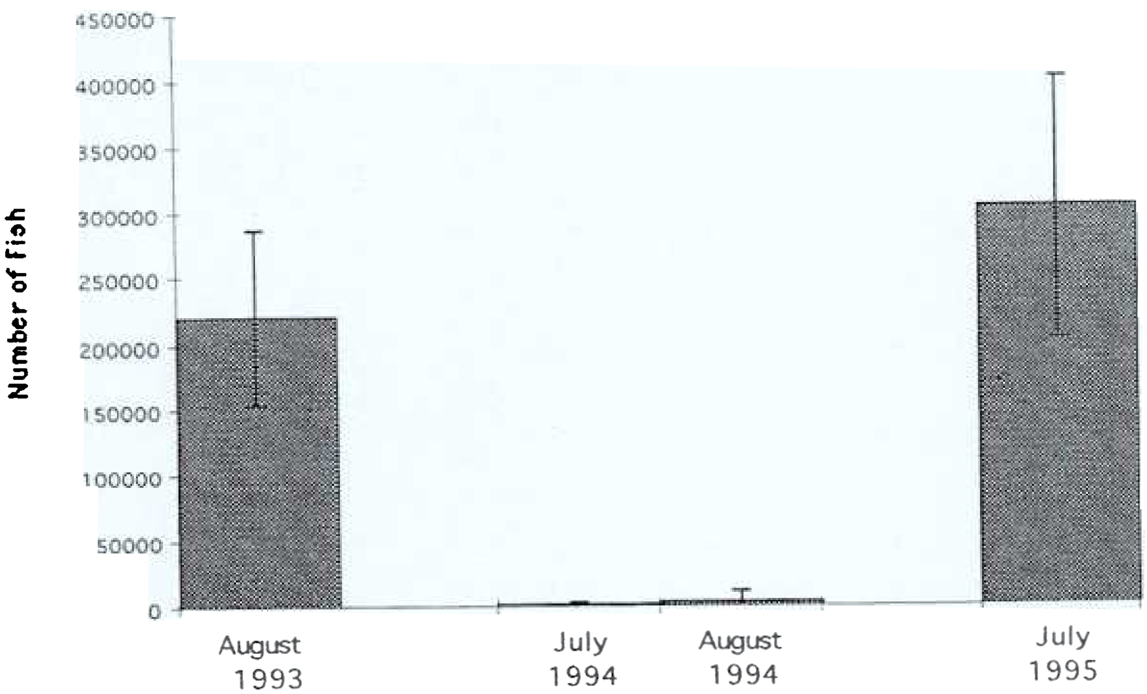


Figure 1-15 Population estimates of young-of-year white perch and 95% confidence interval in Onondaga Lake in 1993, 1994 and 1995.

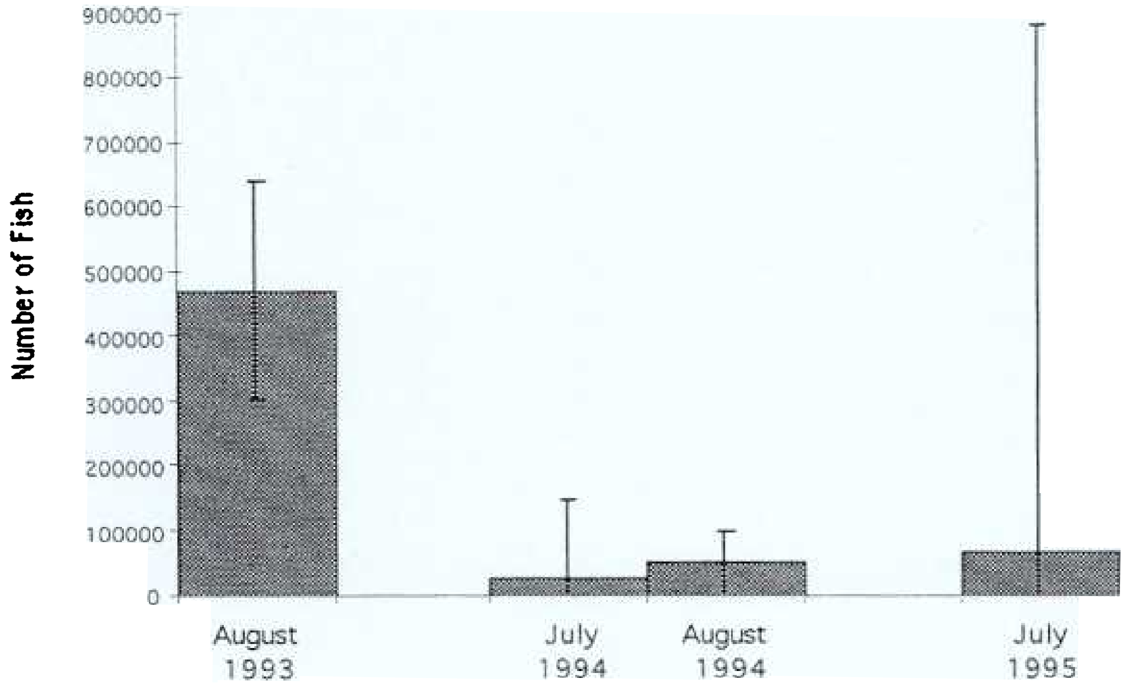


Figure 1-16 Population estimates of young-of-year carp and 95% confidence interval in Onondaga Lake in 1993, 1994 and 1995.

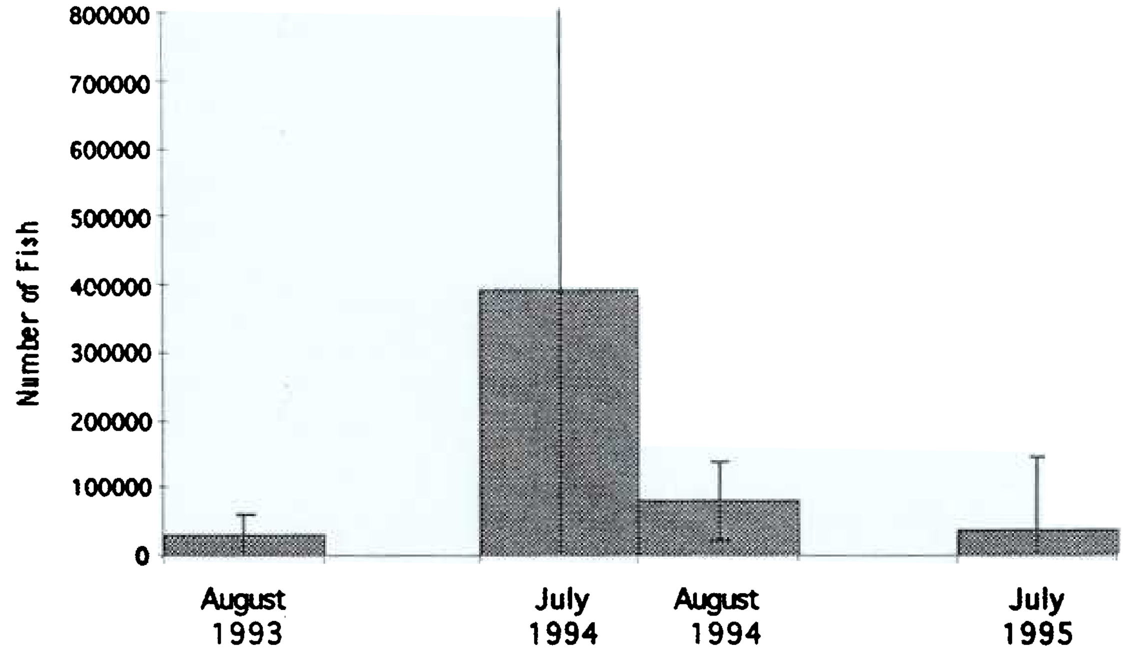


Figure 1-17 Population estimates of young-of-year largemouth bass and 95% confidence interval in Onondaga Lake in 1993, 1994 and 1995. CI in July 1994 extends to 2,000,000.

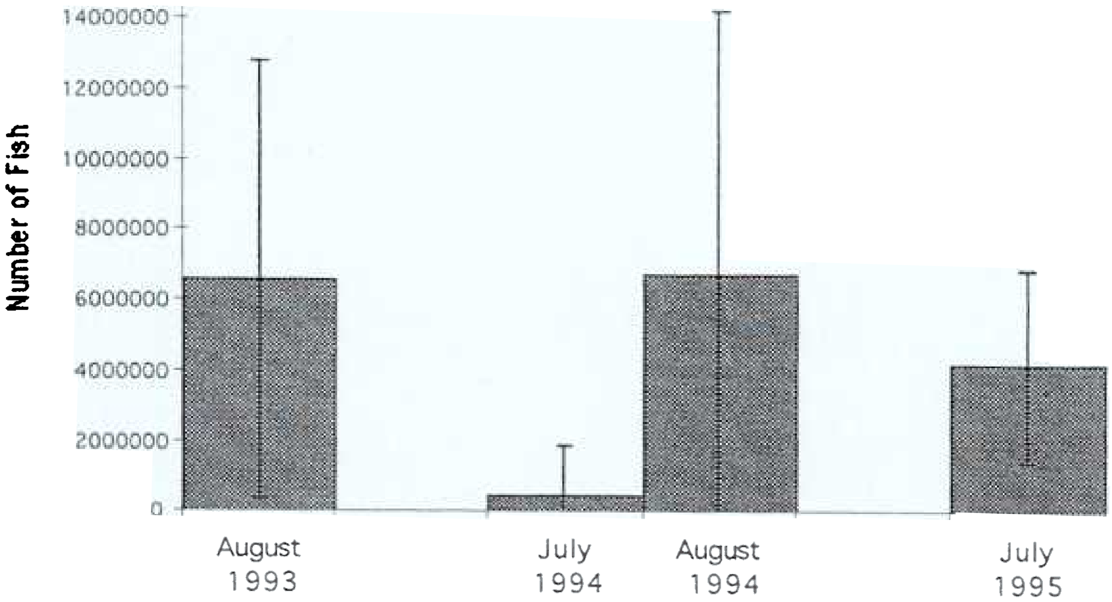


Figure 1-18 Population estimates of young-of-year sunfish and 95% confidence interval in Onondaga Lake in 1993, 1994 and 1995.

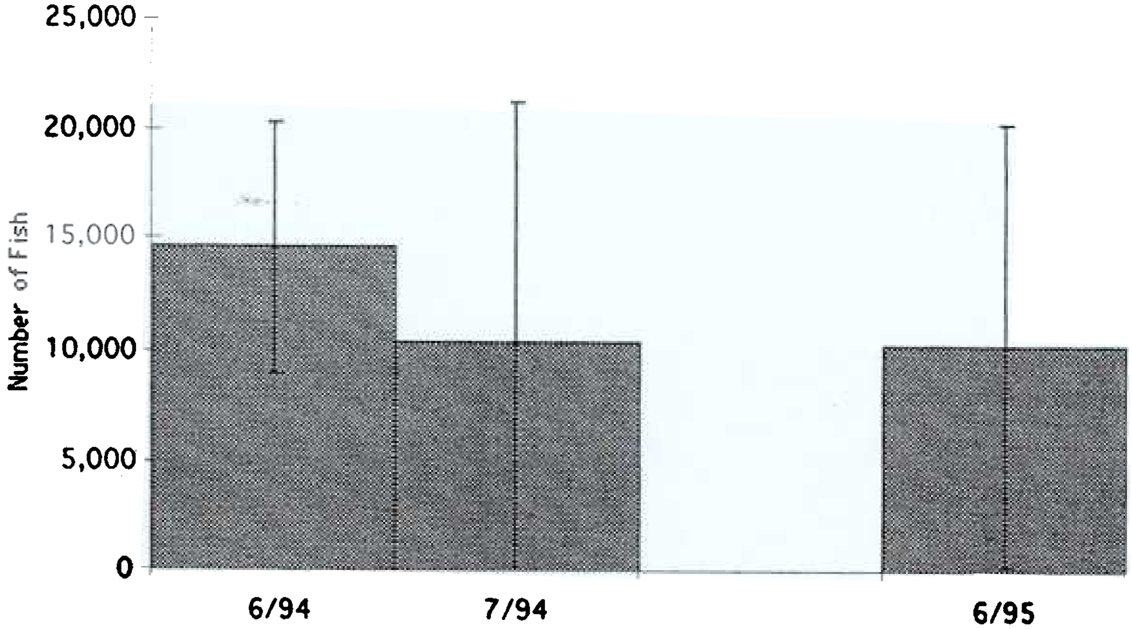


Figure 1-19 Population estimates of one-year-old largemouth bass and 95% confidence interval in Onondaga Lake in the spring of 1994 and 1995.

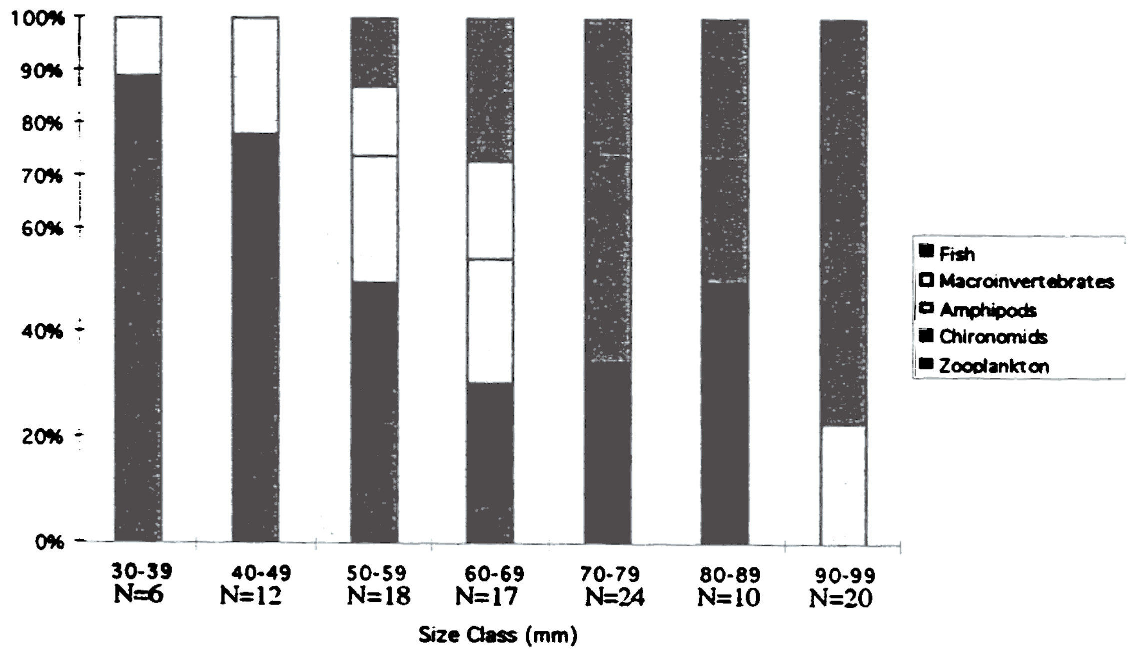


Figure 1-20. Percent composition of diets in seven size classes of young-of-year largemouth bass from Onondaga Lake in 1993 (N=107).

0 POT NT AL MPACT OF WAT R QUALITY ON F
R CRU TM NT

C m mp o F h R p d

T f mi h h ff

m y may l m di b o mi f di /

p d f fi h ful o by

h q h vi m b f w h

f h ch f h

p Th d pe m og h h

m of m va f m ry

d pm d d ff D ld

Ab m may f mi d p y

f h p d oce Th ly f fi h

yp ly f m mi h

d L l. Co mi may

d ff on h ly f h o h vi

m h p t k v m pos f

p m mi d f pos f

rv d mi m f h f

H

O da Lk y h m l

mi k w hy h fi h

m y f hi h Th

m m y op y h mi m

dmi m mm fl h rb

G h mbe f mi O ag Lk h w

f b ff f h mi h k

k w h w fi mpo ds hy y

wi h f fi h w h mi h

f h m ds m

fi h m

H w f

m h f

h m l m m mi m pe

Ono ag Lk 7 / pe (/ C ly

m m O ond Lk k w

w h h o bs d H dy

d 4 / p ly

Do lds 0 mp ed p p f whi k fr m

k mi d w h ppe d dmi m p p

k Th k h mi d k h d h h

d y b h p w b y w mp d d h ggs

h d y ft ut m mb d dy whit k

f m l k on mi d wi h d ppe h d m

d d f di y d f d y wi h Donald on

0 A h h h ff f h h f me heavy m ls h

be di h combi d f f m h vy m al

m pp ly k w

Amm d f m NH xt m ly

h The p p f d mmo

wi h mp nd pH (Th on d R 8 Th m di

f o y m w m wa p ally

b w 0 d m /l gerh H w h

ff oc b wee 0 0 and 0 m /

(Bergerhouse 1992). The median ammonia level in Onondaga Lake has varied from 1. mg/l to 2.8 in 988 to 994. Ammonia levels at the surface of Onondaga Lake varied in 1993 from a low near zero on May 26 to a high of 2.6 mg/l on July 7. Ammonia levels at the surface remained above 2.0 mg/l from June 9 until August 4 in 1994. This period represents most of the growing season for lake fishes.

Thurston and Russo (1981) found that acute toxicity of ammonia in fathead minnows at a pH 7.63 was 0.888 mg/l (0.800 - 0.986 mg/l). These concentrations are well below levels typically measured in Onondaga Lake. Yet results obtained by Aquatic Toxicology Laboratory (1990) using effluent from the Metro sewage treatment plant showed that ammonia levels as high as 1.12 mg/l did not result in a increase in the mortality rate of adult fathead minnows under experimental conditions.

Auer and Auer (1987) found that, at pH 8.75, the acute and chronic toxicity levels of ammonia for walleye were 1.38 mg/l and 0.27 mg/l, respectively. These concentrations are lower than or within the range of the median ammonia concentrations in Onondaga

L. k f m 4. A: h ih O on ag L. k h

f imm w: p y wh y

capt d w h O L k How h O L k

w y d h de h

k

H b h h m: h t

d m typ d d y ly:

h dy M: phyt y h ee

m d o y ou h

y: Th ly f m m: hy

p p w: b y y D J hi

M ds h U Army f Q

f d b o d y w h h

om 4 d

d fi m 4. m: ns f m

4 1 w h w: no h

p m f h l k w 4 h

h rth f L y k. Mos

d b d h m h pa f

milfoil beds and the appearance of Elodea. Eurasian milfoil had been largely confined to the northeast corner of the lake in 1991 and 1992, but by 1994 could be found in most areas of the lake. Elodea was first discovered in the lake in 1992, along the south west shore. By 1994 Elodea could be found in nearly all littoral areas of Onondaga Lake.

Sediments within Onondaga Lake are mostly calcium carbonate in one form or another and are largely of industrial origin. It has been hypothesized that these sediments affect reproductive success of some species in Onondaga Lake (Madsen et al. 1996). Wastebed material, mostly of solid and semi-solid calcium carbonate sediment, has proven to be poor habitat for nesting activity of fishes as shown in Chapter 1 These wastebeds comprise approximately 30% the total shoreline of Onondaga Lake, which is therefore currently unsuitable for the construction of nests by spawning fish. The unstable nature of the oncolites that litter a large portion of the littoral zone may also influence reproductive success of nest-building fishes. During periods of intense wave action the shifting of oncolites may result in smothering, dislodging or physical damage to eggs deposited in nests.

Although the sediments of Onondaga Lake are a potential obstacle to the reproductive success of nest building fishes (sunfish, bass), it would seem unlikely that these same sediments would also have major impacts on the reproductive success of non-nest building fishes (gizzard shad, white perch) because of the lack of contact with sediments by fish and eggs. Yet, these species exhibited the same trend in reproductive success/failure as did the nest builders during the recruitment collapse of 1992 and successful years in 1993 and 1994. Perhaps some other mechanism or combination of mechanisms causes these fluctuations.

Macrophytes provide essential nursery habitat for many species of young-of-year and juvenile fishes in Onondaga Lake. A survey of macrophytes within Onondaga Lake revealed both low diversity and limited distribution in 1991 (Madsen et al. 1993). Macrophyte distribution and diversity seemingly increased from 991 to 1994 (personal observations). Areas devoid of vegetation in

991 contained new beds of macrophytes in 1994. At least three new species of macrophytes have appeared in the lake since 1991 With an increase in available nursery habitat in the lake, t can be expected that the carrying capacity for some young-of-year fishes will increase f nursery habitat is indeed a limiting factor. Littoral species dependent upon macrophytes such as largemouth bass, northern pike and bowfin (cover) and yellow perch and carp (egg deposition) would probably benefit the most; pelagic species such as gizzard shad and white perch would benefit the least from increased vegetation distribution. This increase in macrophyte coverage could initiate a change in the community structure of the lake from its planktivore dominated structure in the early 1990's to a top down structure in the near future.

It is unlikely that macrophyte densities alone could influence overall recruitment strength to the extent observed during our study. Higher macrophyte densities probably reduce the effects of density dependent mortality when reproductive success is high, thus allowing more young-of-year to successfully recruit to the adult population. That is, in years with equal initial reproduction higher macrophyte densities may allow more individuals of some fish species to survive and recruit to the adult population Unfortunately, no quantifiable data on macrophytes have been available since 1991, so determining to what extent the macrophyte community has actually increased and how this increase has impacted young-of-year densities in the lake is not possible.

The unusually cold and wet spring of 1992 may have been detrimental to fish reproduction in Onondaga Lake (Gandino 1996). My analysis revealed no correlation between reproductive success and water temperatures and precipitation (Tables 2- and 2-2). The small sample size, however, prevents ruling out these variables as potential causes or mechanisms behind the reproductive collapse in 1992. Personal communications with Lars Rudstum (Cornell University), Douglas Stang and Tom Chiotti (NYDEC) indicate that alewife and smelt in Lake Ontario failed to reproduce in 1992, and that largemouth bass in New York State generally had a poor reproductive year in 992. found no recent data sets from our region comparable to those in Onondaga Lake, which document levels of reproductive success for an entire fish community.

3.0 HABITAT MANIPULATION OF THE LITTORAL ZONE TO ENHANCE SPAWNING OF NEST BUILDING FISHES AND YOUNG-OF-YEAR HABITAT

Introduction

Nest building fishes, in particular bass (Micropterus spp), have shown a preference for building nests in the immediate vicinity of structure, including boulders, logs and macrophytes (Hoff 1991). In addition to providing cover to spawning adults, newly hatched fish seek cover among adjacent macrophyte beds and other structure (Mraz 1964). In Onondaga Lake, populations of adult nest-building fishes such as largemouth and smallmouth bass are below carrying capacity despite apparently adequate food resources (Gandino 1996). Lack of appropriate spawning and nursery habitat is probably the primary cause of lower than expected bass densities. The lack of adequate spawning substrate was due in part to the presence of oncolites in the littoral zone sediments. The scarcity of appropriate nursery habitats for young-of-year fishes is due, in part, to the lack of aquatic macrophytes in the littoral zone (Madsen et al. 1993).

An Onondaga Lake Littoral Zone Research team was organized by Dr. John Madsen of the US Army Engineers Waterways Experiment

Station in 1991. The research team has cooperated on a range of projects since that time. In 1993 a pilot study was initiated to determine f habitat manipulation was a viable management technique for Onondaga Lake. This project entailed construction of spawning areas adjacent to macrophyte planting zones, monitoring of these structures for plant survival, fish use and macroinvertebrate community structure. My thesis problem entailed design, implementation, monitoring and reporting of the fisheries portion of this project. The following section is the result of this work. The macrophyte and macroinvertebrate sections are included since these are the work of other scientists on the research team. The completed report including macrophyte macroinvertebrate sections may be obtained from the Onondaga Lake Management Conference or through US EPA Region II (Madsen et al 1996).

3.2 Methods

3.2.1 Site Selection

Three sites in Onondaga Lake were selected to receive habitat modifications (Figure 3-1). The first was located in the northwest corner of the lake commonly referred to as Maple Bay; this site received only spawning habitat modifications with no plant enclosure. The second site was located on the west shore just north of the inlet of Nine Mile Creek; this site received both spawning habitat and vegetation modifications. The third site was located on the northeast shore of the lake near a grandstand on shore (the grandstand was removed in 1995); this site also received both spawning habitat and vegetation modifications. Reference sites were established both adjacent to and approximately 300 m away from the manipulation sites (termed near and far reference sites, respectively). The near reference sites were created adjacent to the manipulations and were designed to test for the ability of the spawning areas to increase nesting in the general vicinity of the manipulations not just within the manipulation site itself. The far reference sites were constructed approximately 300 m away from the manipulations so as not to be influenced by the manipulation structures, and were designed to test for the ability of spawning areas and plant enclosures to increase nesting and juvenile density as compared to unmanipulated sites.

3.2.2 Site Construction

Spawning and planting sites were constructed adjacent to each other. Sites were 20 x 20 m in size (Fig. 3-2). Planting sites were enclosed in chicken wire mesh to prevent nuisance animals (such as carp and muskrats) from uprooting propagules (mesh was one diameter and large enough to allow YOY fishes to move between sites). The Maple Bay planting site was left unplanted but the 20 x 20 m area was still delineated. A hay-bail wave break was constructed approximately 10 m from the lakeward side of the Nine Mile and Grandstand sites to protect macrophyte propagules

Within each spawning site two types of Spawning Improvement Structures (SSIS's) were constructed: gravel filled pools (spawning platforms) and half-logs. Spawning platforms were d of m d m 0 m d p w di p

f l d w h # d # pp m ly m di m

H w m de f m m cm d h dw d

b m h d ch d o block.

d f h lf w b ed on h d by H ff 1

W k W hi ch p w p w g

p f m w d m m p rt 0 7 m of

Th h f w d mly pl d ex

k w d d f p w pl m h

3.2.3 Monitoring

U f p w w d mi d from

ch m p d f

m d 14 m pp m ly d y from J ne 4

J ly 1 W y ly d mi ed whi h d y

b ld be made D d f w b d y

bserva w m d by d d l di g h w b k

h w f m p by d d di

d h p w g h M le y t O day w h

m te ty o de w h di b rv ti w

made m boa pped with l me

ma d be we p w p m w h m m d b

fi h

N d w ke he d d h

p h o fi of h p w d

w d (fi h di

di b d b o fi h b b do ed f

d p F h di w d fi d p wh

w y p mi d

U f p d d f f 00 m

way by h w d mi d f m h

mi w p T m w w pl d h pl

d h p v f T p w

f f h l h b im m

d by h m p did f d

h f o d h d if h p w

h f T p w h ked. y

h day fr m J ly 4 A 0. T w hecked f

days at the Grandstand site and 24 days at the Nine Mile site. All fish were identified to species (bluegill and pumpkinseed were identified as "sunfish") and counted. Sub-samples of largemouth bass and sunfish were measured (total length in mm) and weighed (nearest 0.1 in g).

Sunfish used for lakewide growth averages were collected from yearly monitoring sites in Onondaga Lake as detailed in Ringler et al. (1996). Two 30 m sweeps were made at biweekly intervals, parallel to the shoreline in water < 1m deep using a 20 m bag seine constructed of 0.635 cm mesh. Sunfish were measured (total length in mm) and weighed (nearest 0.1 in g).

3.2.4 Analysis

A 3 by 3 between-group ANOVA was used to test for nesting and juvenile density differences among sites (Nine Mile, Maple Bay, Grandstand) and treatment type (manipulation near reference (adjacent), far reference (300 m away)). A post hoc Sheffe test was used to test for interactions between combinations of sites and treatments (example; Nine Mile Manipulation and Maple Bay Near

Reference). Data for both nesting and young-of-year abundance were transformed (natural log) to meet the normal distribution and homogeneity of variance assumptions associated with the ANOVA technique.

3.2.5 Habitat Suitability Index

A habitat suitability index (HSI) was calculated at the Nine Mile site for largemouth bass before and after construction of manipulation sites for cover and reproduction potential. These models are general hypotheses of species-habitat relationships, so the models may vary according to geographic area (Stuber, Gebhart and Maughan, 1982). HSI calculations are based on values from 0 (completely unsuitable) to 1.0 (ideal habitat)

The following equations were used (Stuber et al., 1982):

$$\text{Cover HSI} = \{V_2 * (V_3+V_4)/2 * V_{16} * V_{18}\}^{1/4}$$

$$\text{Reproduction HSI} = (V_2 * V_9 * V_{15} * V_{17})^{1/4}$$

Where; V_2= Suitability Index for percent lacustrine area ≤ 6m.

Suitability Index for percent bottom cover within littoral areas during summer (Adult, Juvenile).

V_4= Suitability Index for percent bottom cover in littoral areas during summer (Fry).

V_9 = Suitability Index for average weekly mean temperature within littoral areas during spawning and incubation.

V_{15}= Suitability Index for substrate composition within littoral areas.

V_{16}= Suitability Index for average water level fluctuation during growing season.

V_{17}= Suitability Index for maximum water level fluctuation during spawning.

V_{18}= Suitability Index average water level fluctuation during fry growing season.

Because our manipulations affected only the percentage cover and substrate type, V_3, V_4, and V_{15} were the only variables changed between pre- and post-manipulation. **Several assumptions were** made when determining suitability indices. Because of the abnormal sediment type in Onondaga Lake, no category existed in the HSI to determine a value for use in the calculations for Onondaga Lake (Stuber et al. 1982). The industrial origin of much of the sediment led us to choose the lowest value used in the original HSI model (0.3) for our pre-manipulation value. Cover within pre-treatment sites was virtually absent; suitability indices based on 1.5% cover were used in the calculations

3.3 Results and Discussion

3.3.1 Nesting

We observed 983 nests in the manipulated spawning sites, within near reference sites (adjacent to manipulation) and 59 in far reference areas (300 m away from manipulations) (Figure 3-3). Of the fish that built nests within manipulation areas pumpkinseed sunfish comprised 51%, largemouth bass 2%, and bluegill (*Lepomis macrochirus.*) 2%. Positive identification of species building the remaining nests was not possible. Overall, there was a statistically significant difference in the number of nests built in manipulation and reference sites ($p < 0.0001$; Table 3-3). Spawning manipulations were successful in attracting spawning fishes; a Sheffe test showed that manipulation areas had significantly more nests ($p < 0.0001$) than either near or far reference areas (Table 3-4). Also, the near reference sites had significantly more nests ($p < 0.01$) than did far reference areas. This result suggests that the presence of complex structures probably influenced nesting densities in the immediate vicinity of the manipulation sites.

Within manipulation areas most pumpkinseeds (83%-99%) and bluegill (50%-100%) built nests near (but not directly on) spawning platforms and accompanying half-logs. In contrast, most largemouth bass (90%-92%) built nests directly on top of spawning platforms (Figure 3-4). In reference areas 11%-50% of nests were built around two of the 4-cm-diameter stakes that marked the outer corners of the sites (Figure 3-5). A substantial number of sunfish were also observed nesting against the wire mesh plant enclosures, although no counts were taken.

The location of sites seemed to influence nesting densities. The complete Nine Mile site (including reference areas) attracted more nest-building fish than did either the Grandstand or Maple Bay sites ($p < 0.001$ and $p < 0.01$ respectively; Table 3-6). The manipulation only area at the Nine Mile site contained significantly more nests (41.3 nests/day) than did the Grandstands manipulation area (0.7 nest/day, $p < 0.001$) (Fig. 3-6). The near reference area at the Nine Mile site contained significantly more nests (9.8 nests/day) than did the Maple Bay near reference area (0.94 nests/day, $p < 0.05$). The number of nests observed in the Grandstand and Maple Bay manipulation and near reference areas were not statistically different from each other ($p = 0.40$ and $p = 0.99$ respectively).

The significantly higher nest densities observed within manipulated sites compared to reference areas suggests that habitat manipulations attracted nest-building fish. That most sunfish nested near spawning platforms (instead of on top) is surprising, since nests (especially of bass) are usually built next to some type of cover (Tester 1930; Mraz 1964; Hoff 1991). The prediction was that bass would also build a majority of nests on these artificial structures. It is unknown whether bass were able to ascertain the difference in substrate that filled the platforms or if bass under these conditions preferred to nest on a elevated surface. The high proportion of fish that spawned near fencing and stakes at enclosures and in reference areas suggested that spawning cover is currently a limiting factor in Onondaga Lake

Differences in nesting density among manipulation sites probably resulted from natural variability in fish population densities throughout the lake, although we cannot rule out subtle site preferences by spawning fish. The lack of bass nests at the Nine Mile site may have been caused by the high density of sunfish nests there, since bass usually build nests isolated from those of other centrarchids (Hoff 1991).

The Maple Bay manipulation was expected to have the fewest number of nests because it received no wave break or plant enclosure. Yet, there was no statistical difference between the Maple Bay site and the fully manipulated grandstand site. This suggests that the spawning site improvement structures were what attracted most fish to our sites and not the protection of the wave break. However, we also found significantly more nests in near reference sites than in far reference sites. This suggests that the full manipulation site including wave break and enclosure may also attract nest-building fishes. These results in association with the observed differences in nesting densities between sites would suggest that future manipulation sites may have varying effects depending on their spatial distribution within Onondaga Lake. In any case, it appears clear that nest building fishes in Onondaga Lake can be successfully attracted to areas with adequate spawning cover.

Our results closely parallel those of Hoff (1991), who studied smallmouth bass lakes in Wisconsin. He found that not only does cover attract nesting bass, but it may also induce a larger percentage of males to nest. Nest densities increased from 137% to 287% when half-log structures were added to lakes with adequate substrate. His conclusion was that "nest density, successful density, and first-year recruitment of smallmouth bass can be increased significantly through properly designed construction and installation of nesting cover devices in lakes with low densities, poor quality and/or quantity of nesting cover, and first-year recruitment rates.

3.3.2 Habitat Suitability Index

The results of our pre- and post-manipulation Habitat Suitability Indices show that these types of manipulations potentially increase the habitat quality for largemouth bass in Onondaga Lake if imposed on a larger scale. HSI's for cover rose from 0.595 prior to manipulation to 0.707 after manipulation. HSI's for reproduction rose from 0.647 prior to manipulation to 0.852

after manipulation (Table 3-1). These results show that these types of manipulation can potentially increase the habitat quality for largemouth bass in Onondaga Lake if imposed on a larger scale. values obtained for the reproduction HSI document the physical habitat improvements that our manipulations achieved but do not take into account other problems that may affect reproduction in Onondaga Lake, such as elevated ammonia levels and heavy metal contamination. Therefore the high HSI value for reproduction (0.852) calculated for our post manipulation site probably does accurately reflect the current reproductive potential within Onondaga Lake.

3.3.3 Juvenile Abundance and Growth

Although the vegetation enclosures were successful in achieving rooted plant growth, most of the cover created in enclosures was from filamentous algae that covered most of the inside of plant enclosures for the duration of the summer (Madsen 1996). More juvenile fishes were captured in plant enclosures (10,888) than in far reference sites (1,549, $p < 0.0001$) (Table 3-8 and Fig. 3-7). A total of fifteen species were captured in enclosures and far reference areas (Table 3-2). Carp and sunfish dominated the catch in both enclosures (68.9% and 27.8% respectively) and in far reference areas (57.5% and 38.7% respectively). **Largemouth bass** constituted 0.2% of the total catch, and their abundance was 9 times higher in enclosures than in reference sites (Figure 3-9).

Juvenile fish densities differed between sites. **The overall** Nine Mile site attracted more juveniles (174.6/day) than did the overall Grandstand site (78.0/day, $p < 0.05$; Table 3-9). However, **differences in juvenile density between enclosures were not** statistically different from each other ($p = 0.14$; Table 3-10).

Plant enclosures did not appear to significantly **increase** growth of juvenile sunfish when compared to far reference sites and **lakewide means.** Only sunfish juveniles were caught in sufficient numbers to test for differences in size of fish among enclosures, **reference sites and lakewide means. Mean sunfish size in both the** Nine Mile and Grandstand enclosures was less than sunfish size in the far reference sites at the end of July and end of August. Also Grandstand enclosure sunfish were also smaller than the lakewide mean at the end of July (Figure 3-10). However these size differences were not significantly different (p=0.07 to 0.99).

The nursery habitat created by the planted enclosures was very successful in attracting juvenile fishes. The low density of aquatic vegetation in Onondaga Lake probably limits the amount of adequate nursery habitat available to juvenile fish. Any areas with vegetation are probably in high demand by juveniles, especially in years such as 1993, when reproduction by fishes within the lake was successful. It is therefore not surprising that the plant enclosures had significantly higher densities of juveniles than did their reference sites, even though filamentous algae was the primary habitat type in the enclosures and not rooted aquatic plants.

The differences in juvenile density between the two planted (enclosed) sites probably reflect natural variability in population density around the lake, although the higher density of sunfish at the Grandstand site may reflect the higher total biomass of plants at this site. The lower density of largemouth bass juveniles in both sites when compared to sunfish probably indicates natural differences in the population size of these two species in Onondaga Lake (Gandino 1996).

The larger size of juvenile sunfish in reference sites in comparison to enclosures could reflect natural variability within the population and the relatively small sample size encountered. It cannot be ruled out, however, that higher densities of juveniles within enclosures created periodic food shortages that resulted in decreased growth rates.

4 A M d P d R p of h Litt H b
m m

ppe th h d ns y of id he
fi ly d h igh h bi m p Onondaga
Lake Th ypes of m pul f impos d on k wide
ld be d fo m m g mo h b fi h y
one ha m y approaches h po f l k f h
da b fi h g im h h im l m h b id
rth pik m y o from he imp m

N ve imp he fo m o h pr pag ion f p
p b y p p wi wi h m phyt beds How h
b fit f b m w k y w igh
eg mpa oc d wi h sed rp m

The oc nd iumber of f m p
ed be d m d h fi e of b
popu it b ology w need to be de m ed b fore an ra
im f he a he m ip l d ca be mad Th
d h p ct d imbe f b h w o wn w h fu

manipulation areas, the success rate of those nests, the survivorship of eggs and larvae, and density of young-of-year bass that newly created nursery habitat can hold. Since it is unlikely that many manipulation sites will be constructed at once, the initial permanent constructions can be studied to acquire a better estimate of needed variables for determining total area needed for littoral manipulation.

Given the data already available, it is possible to provide a preliminary estimate of the number of yearling bass that will be needed to produce adult populations (3 to 10 years old) that approach or exceed the New York State mean number per hectare. The population size of largemouth bass greater than 100 mm in Onondaga lake is currently about 1 bass/ha (95% CI = 0.3 - 5) (Gandino 1996). In contrast, the mean number of largemouth bass greater than 254 mm (approximately 3 years old in Onondaga Lake) in New York State lakes, ponds and reservoirs is 16.0/ha with a range of 0.3 to 68.4 /ha (NE Div. AFS 1993). developed a basic model of the number of yearling bass in Onondaga Lake and the resulting population that would exist if the number of yearlings remained constant for a ten-y p od :q :m ch y and no mov men oc :d

o f he k T bl Th m d w deve ped

hyp h y p p d % m y

im d by d 9 fo d la mou h bas

Ono d Lak M y f you ge b m y l

hos f d d fu d m y k ly y

k ondi o change The mode y g popu io

f 0 000 wh h h im d mbe f y Onondag

L k 9 4 d d h hypo h ed m im im mber

y h Onondag Lak ould produc 9 ee Se on f

hi h Th hyp h l de y f d g m h b

ft y t m b /h Th d y

w h he 9 %C fo dult gemou h bas de si y d :d

by G di 6 For d lt d ity h h b /h

im f h k pop m w h h k

wou d need o h ve veraged bout 000 y pe year F

em h b Onondag Lak o q he e

de fo N w Y rk bass/h y g m w d eed

ve age about 0 000 lly fo y rs or 100 000 ly

f fi et d b ld p o N w York m d

This is a five fold increase in hypothesized maximum current recruitment levels and a 17 fold increase over estimated average recruitment levels over the last ten years, based on current adult populations (Gandino 1996). In order for Onondaga Lake to equal maximum densities for largemouth bass in New York (68 bass/ha) yearling recruitment would need average about 200,000 for ten years. This is a 20 fold increase in hypothesized maximum current recruitment levels and a 67 fold increase over estimated average recruitment levels over the last ten years. It is unlikely that Onondaga Lake could ever approach maximum bass densities, due to the bathymetry of the lake, but, reaching average largemouth bass densities in New York lakes seems an achievable goal if reproductive and nursery habitat is improved.

The location of manipulation areas within Onondaga Lake will be an important. Enhancing only areas that already produce moderate numbers of bass will likely not result in dramatic improvements. Likewise, enhancing only the most degraded sites within the lake risks failure if bass do not inhabit the areas before spawning or if planted and naturally occurring vegetation will not grow due to poor q y :h h ıb w ık y he m ıdvi bl ıh

wid nge o arou ıd he ık The f as be

pe m ly m ıp ıd ıh ld be p ırt of :h ık wh

k ly immed ly he h b uch :h N M

C :k :d d :h :m y m ıp o dy Th w

ll ıw :h y f ırth ıdy d :e m :ot needed

h b f impa :t b p ıp nd ıd

Secondary ıh ld i ıd ha do pport

g :y :ry h b A w h l

enough nes be :wee he m ıd L :y C eek w eem

be ıd c ıdid es C ıf :h w ds ıf

he w ıh no ıdvi ıb due :h m o nd

ıo ıb ıt m d ff :h Po

ıhould w dep hs ha ag m im

ıho ld be e y f m pr ıh me

from ık g or be ıg er :d by oft :dim

Table 3-1 Habitat Suitability Indices at pre-and post-treatment manipulation sites in Onondaga Lake, 1993 (Edwards et al. 1983).

	Percent bottom cover (Adult) value	Percent bottom cover (Fry) value	Substrate composition value	Cover HSI	Reproduction HSI
Pre Manipulation	0.2	0.05	0.3	0.595	0.647
Post Manipulation	0.3	0.2	0.9	0.707	0.852

Table 3-2 Total number of individuals and percent of catch of each species caught in enclosures and reference sites during 1993 in Onondaga Lake.

Species	Total Number and Percent Captured in Plant Enclosures	Total Number and Percent Captured in Far Reference Sites
Carp	7,500 68.9%	891 57.5%
Sunfish	3023 27.8%	599 38.7%
Banded Killifish	184 1.7%	1 0.1%
White Sucker	66 0.6%	1 0.1%
Largemouth Bass	27 0.2%	3 0.2%
White Perch	20 0.2%	29 1.9%
Brown Bullhead	20 0.2%	3 0.2%
Fathead Minnow	19 0.2%	2 0.1%
Yellow Perch	13 0.1%	15 1.0%
Gizzard Shad	11 0.1%	2 0.1%
Golden Shiner	2 <0.1%	0
Smallmouth Bass	1 <0.1%	1 0.1%
Central Mudminnow	1, <0.1%	0
Logperch	0	1 0.1%
Bluntnose Minnow	0	1 0.1%

Table 3-3. ANOVA table for analysis of differences between nesting densities in each type of manipulation (manipulation, near reference and far reference) in Onondaga Lake, 1993.

	Sums of Squares	df	Mean Square	F	p-level
Effect	90.51078	2	45.25539	96.75215	0.0000000
Error	64.54889	138	0.46775		

Table 3-4. Sheffe analysis of differences between nesting densities in each type of manipulation (manipulation, near reference and far reference) in Onondaga Lake, 1993.

	1 Manipulation	{2} Near Reference	{3} Far Reference
Manipulation {1}	---------	0.0000000	0.0000000
Near Reference {2}	0.0000000	---------	0.0073581
Far Reference {3}	0.0000000	0.0073581	---------

Table 3-5 ANOVA table for analysis of differences between nesting densities at each site of manipulation (Nine Mile, Grandstand, Maple Bay) in Onondaga Lake, 1993.

	Sums of Squares	df	Mean Square	F	p-level
Effect	10.44767	2	5.223833	11.16811	0.0000320
Error	64.54889	138	0.467746		

Table 3-6 Sheffe analysis of differences between nesting densities in each site of manipulation (Nine Mile, Grandstand, Maple Bay) in Onondaga Lake, 1993.

	1 Nine Mile	{2} Grandstand	{3} Maple Bay
Nine Mile {1}	---------	0.0001775	0.0010589
Grandstand {2}	0.0001775	---------	0.8989624
Maple Bay {3}	0.0010589	0.8989624	---------

Table 3-7 P - levels for Sheffe analysis of the interaction between nesting densities in each site and type of manipulation (Nine Mile= Mile, Grandstand= Grand, Maple Bay= Maple; Manipulation= Manip., Near reference= N.ref, Far Reference = F.ref)) in Onondaga Lake, 1993.

	{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}
Mile Manip. {1}	—	.00032	.58279	.00001	.00000	.00000	.00000	.00000	.00000
Grand Manip. {2}	.00032	—	.39953	.99994	.05946	.01030	.00047	.08066	.00109
Maple Manip. {3}	.58279	.39953	—	.13342	.00000	.00000	.00000	.00000	.00000
Mile . N.ref {4}	.00001	.99994	.13342	—	.19602	.04849	.00336	.24692	.00663
Grand N.ref {5}	.00000	.05946	.00000	.19602	—	.99996	.97570	1.0000	.98086
Maple N.ref {6}	.00000	.01030	.00000	.04849	.99996	—	.99931	.99982	.99946
Mile . F.ref {7}	.00000	.00047	.00000	.00336	.97570	.99931	—	.99982	1.0000
Grand F.ref {8}	.00000	.08066	.00000	.24692	1.0000	.99982	.99982	—	.96670
Maple F.ref {9}	.00000	.00109	.00000	.00663	.98086	.99946	1.0000	.96670	—

Table 3-8 ANOVA table for analysis of differences between juvenile densities in plant enclosures and far reference sites) in Onondaga Lake, 1993.

	Sums of Squares	df	Mean Square	F	p-level
Effect	211.6162	1	211.6162	130.9292	0.0000000
Error	155.1614	96	1.6163		

Table 3-9. ANOVA table for analysis of differences between juvenile densities at Nine Mile and the Grandstand sites in Onondaga Lake, 1993.

	Sums of Squares	df	Mean Square	F	p-level
Effect	6.8783	1	6.8783	4.25566	0.0418199
Error	155.1614	96	1.6163		

Table 3-10. P - levels for Sheffe analysis of the interaction between juvenile densities in each site and type of manipulation performed (Nine Mile=Mile, Grandstand= Grand, ;Plant Enclosure = Encl.,Far Reference = F.ref) in Onondaga Lake, 1993.

	{1} Mile Encl.	{2} Grand Encl.	{3} Mile F.ref.	{4} Grand F.ref.
Mile Encl. {1}	----	0.1436570	0.0000000	0.0000000
Grand Encl. {2}	0.1436570	----	0.0000001	0.0000000
Mile F.ref. {3}	0.0000000	0.0000001	----	0.9566180
Grand F.ref. {4}	0.0000000	0.0000000	0.9566180	----

Table 3-11 Hypothetical model of adult largemouth bass densities in Onondaga Lake with various yearling recruitment levels, assuming 53% annual mortality, constant recruitment, and no immigration or emigration.

AGE	# adults/ha with 3000 1+ Bass	# adults/ha with 10000 1+ Bass	# adults/ha with 20000 1+ Bass	# adults/ha with 30000 1+ Bass	# adults/ha with 40000 1+ Bass	# adults/ha with 50000 1+ Bass	# adults/ha with 200,000 1+ Bass
1	2.5	8.4	16.8	25.2	33.6	42.0	168.0
2	1.2	3.9	7.9	11.8	15.8	19.7	79.0
3	0.6	1.9	3.7	5.6	7.4	9.2	37.1
4	0.3	0.9	1.7	2.6	3.5	4.3	17.4
5	0.1	0.4	0.8	1.2	1.6	2.0	8.1
6	0.06	0.2	0.4	0.6	0.8	1.0	3.9
7	0.03	0.09	0.2	0.3	0.4	0.5	1.8
8	0.01	0.04	0.08	0.1	0.2	0.2	0.9
9	0.006	0.02	0.04	0.06	0.08	0.1	0.4
10	0.002	0.01	0.02	0.03	0.04	0.05	0.2
Total	**1.0**	**3.5**	**7.0**	**10.5**	**14.0**	**17.5**	**69.9**

Figure 3-1. Location of littoral zone manipulation sites in Onondaga Lake, 1993.

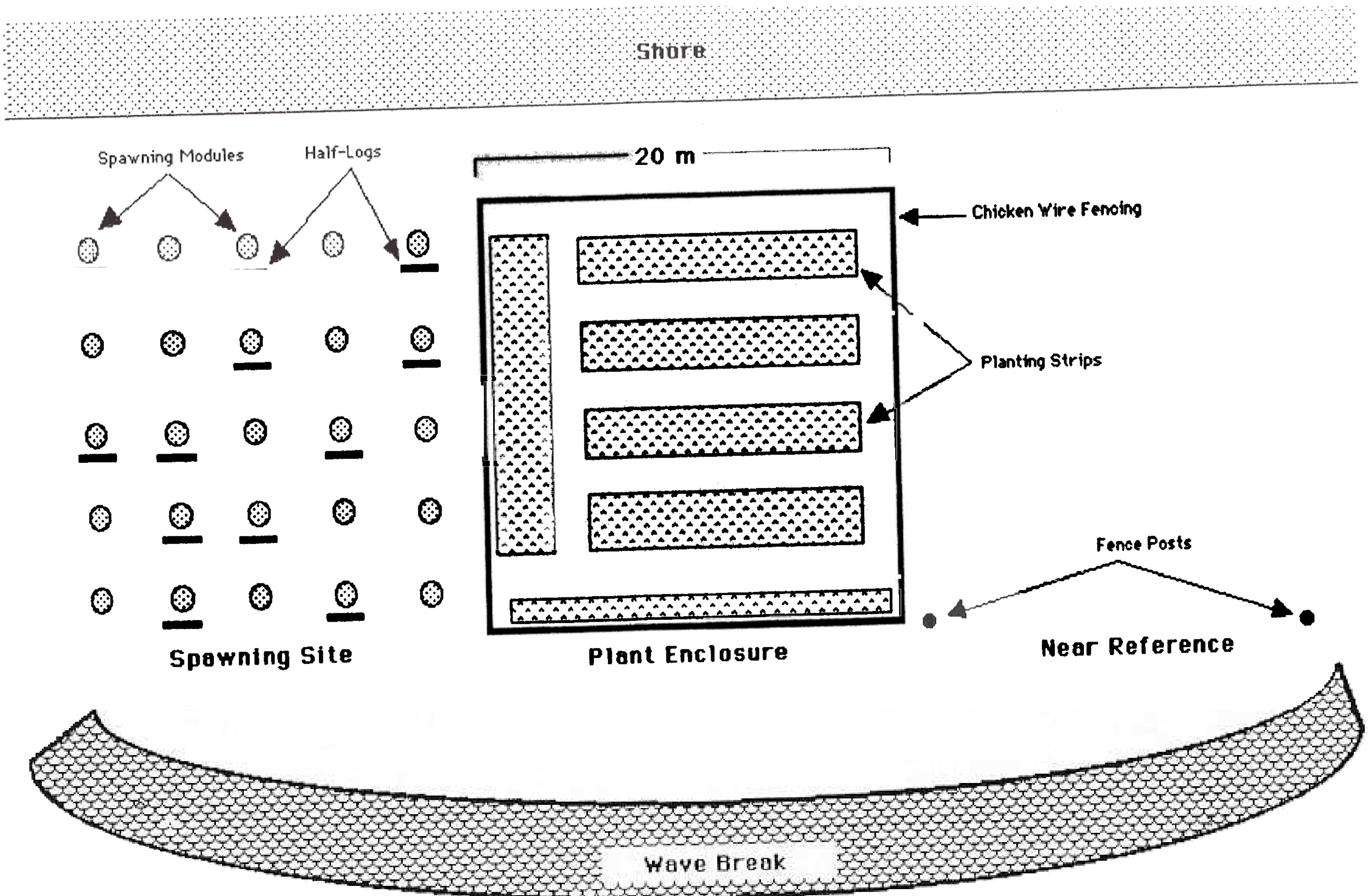


Figure 3-2. Diagram of a full littoral zone manipulation site constructed in Onondaga Lake, 1993.

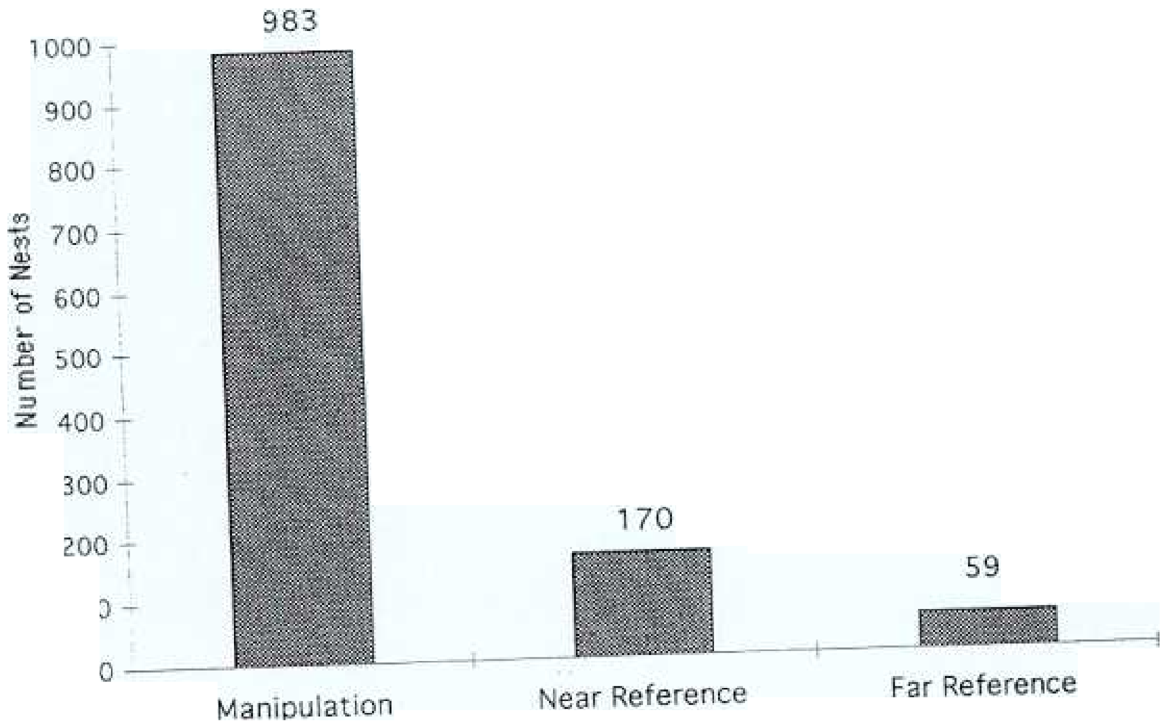


Figure 3-3. Total number of nests observed within spawning manipulation and reference sites in Onondaga Lake, 1993.

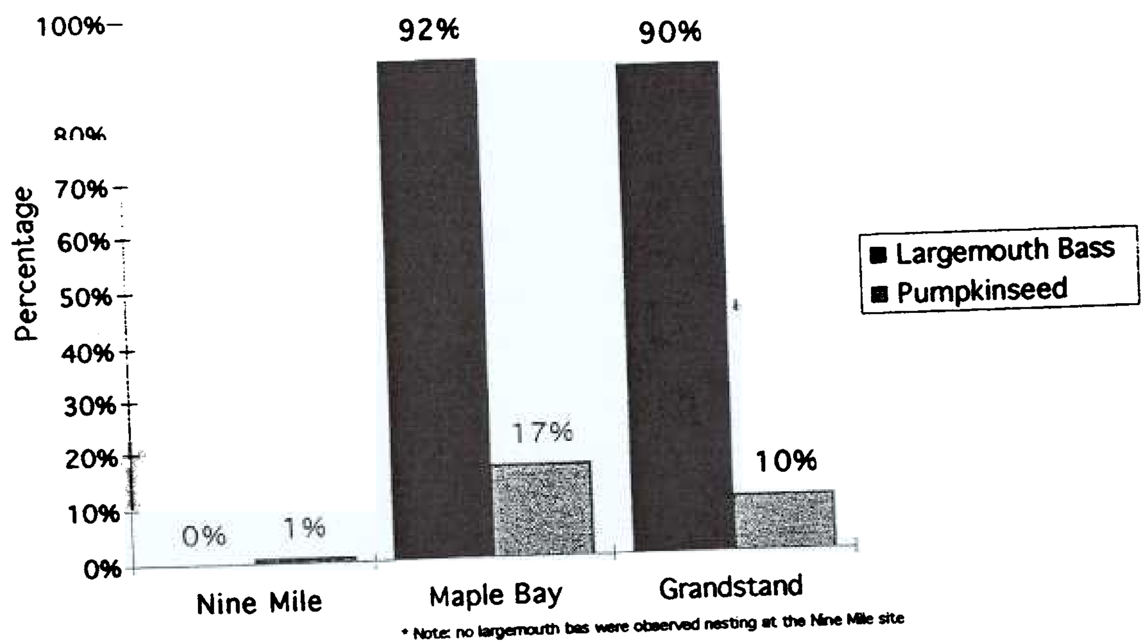


Figure 3-4. Percentage of largemouth bass and pumpkinseed utilizing spawning modules in Onondaga Lake, 1993.

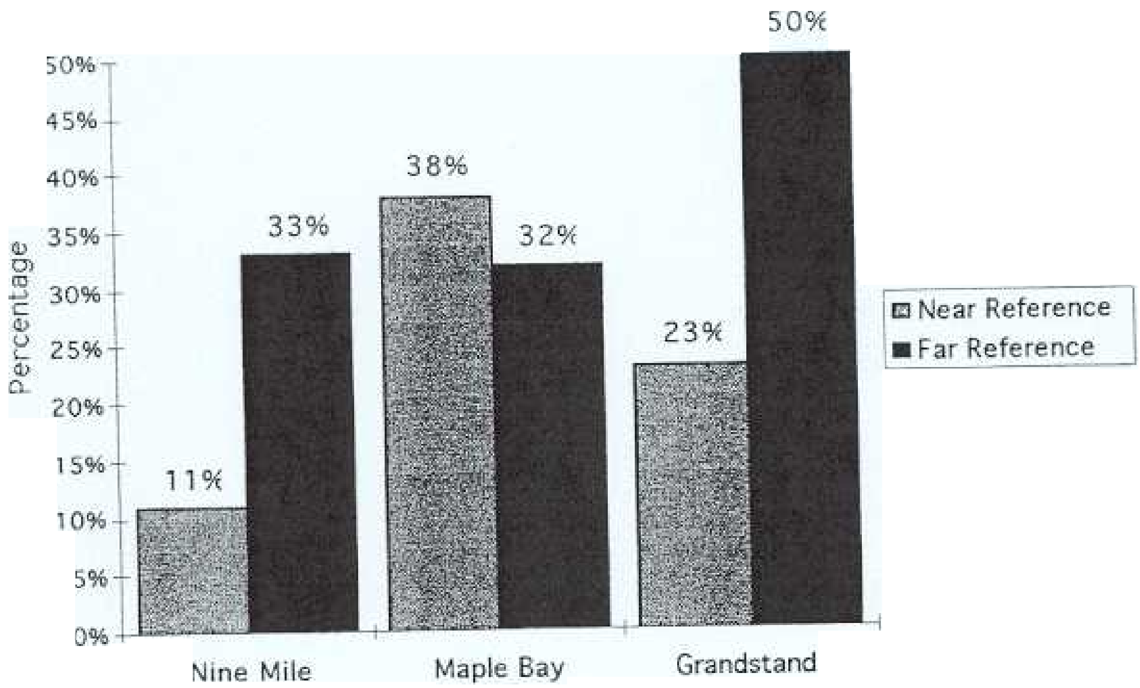


Figure 3-5. The percentage of nests in reference areas building directly around two 4cm diameter stakes marking the outer boundary of the sites in Onondaga Lake, 1993.

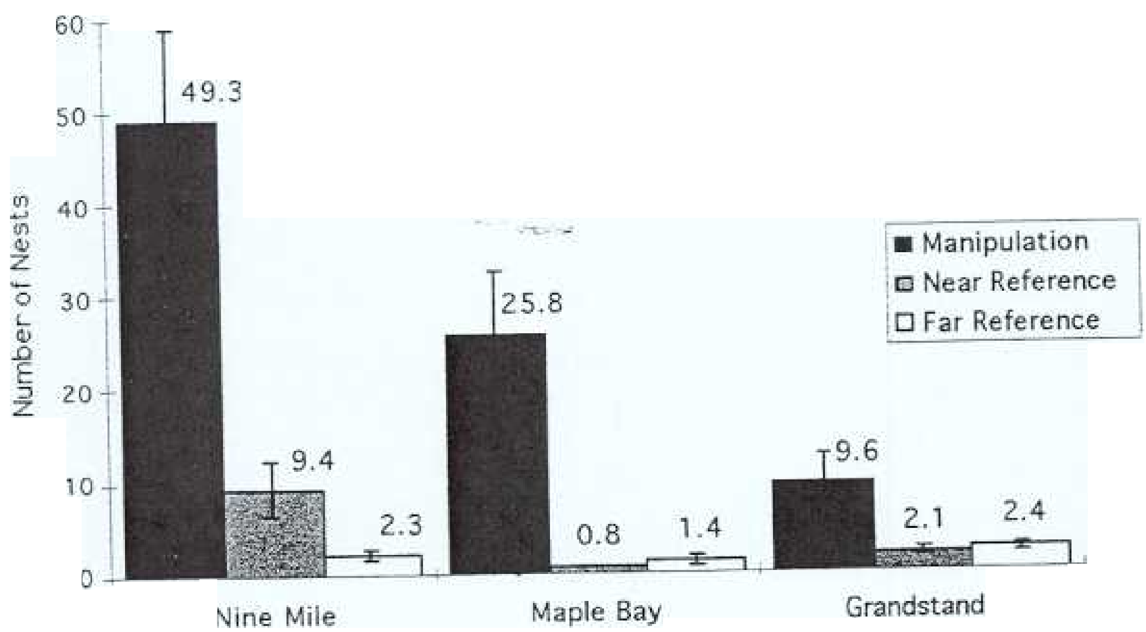


Figure 3-6. Number of nests per sample day at each experimental site in Onondaga Lake, 1993 (error bars are standard deviation).

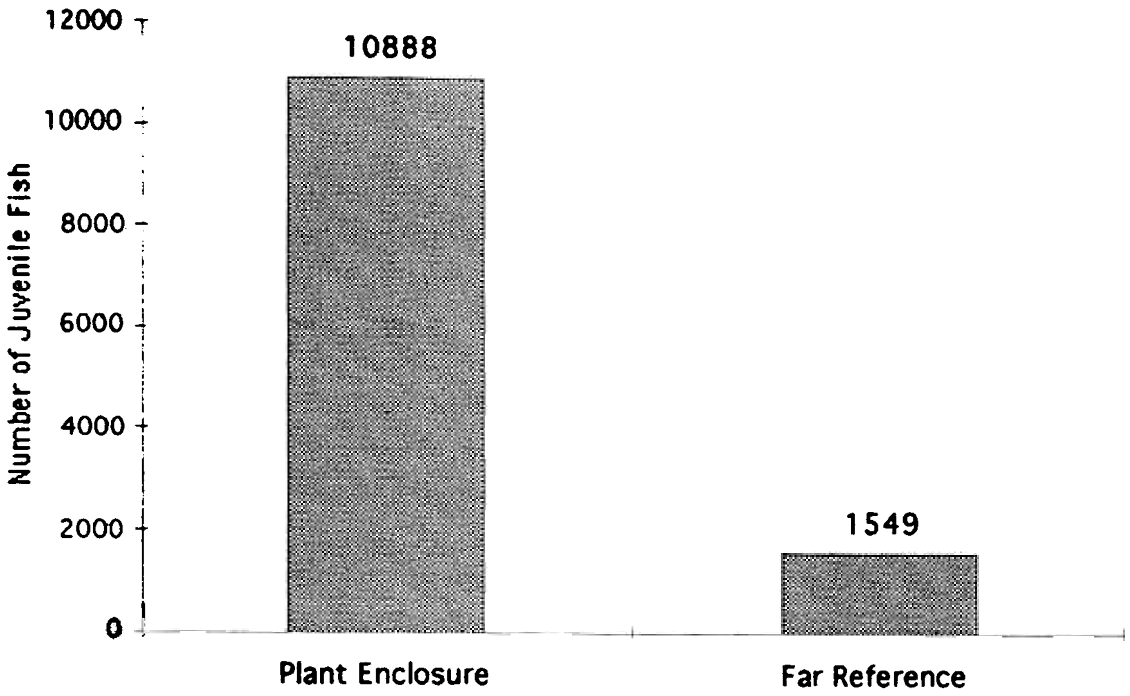


Figure 3-7. Total catch of juvenile fishes in plant enclosures and far reference sites in Onondaga Lake, 1993.

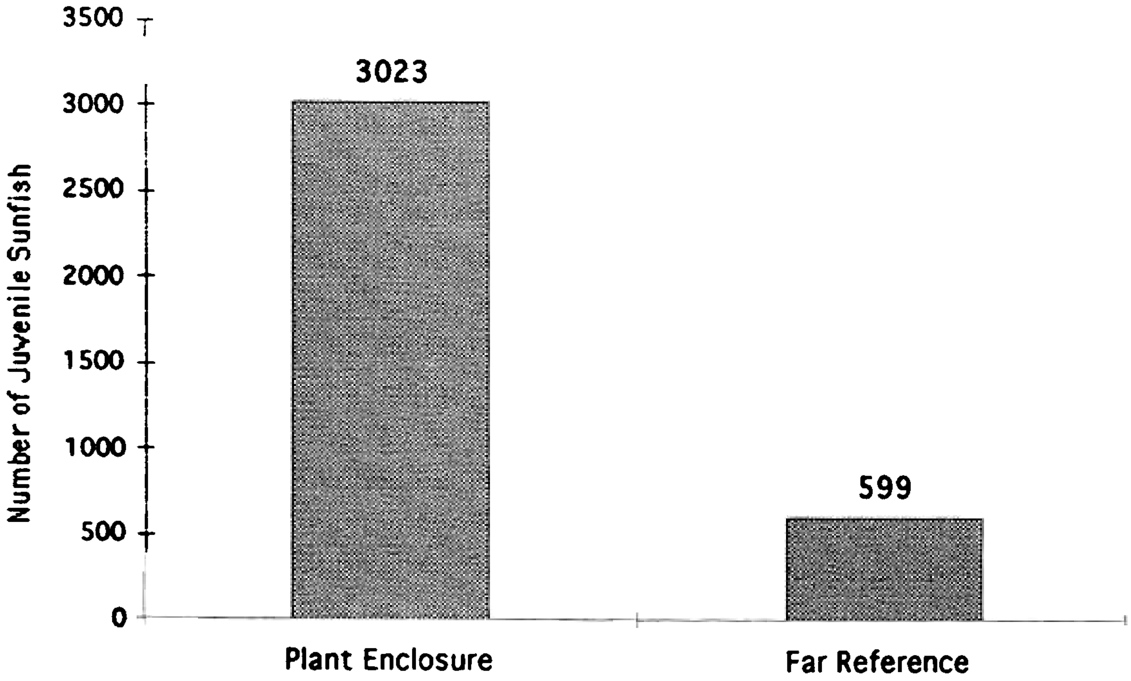


Figure 3-8. Total catch of juvenile sunfish in plant enclosures and far reference sites in Onondaga Lake, 1993.

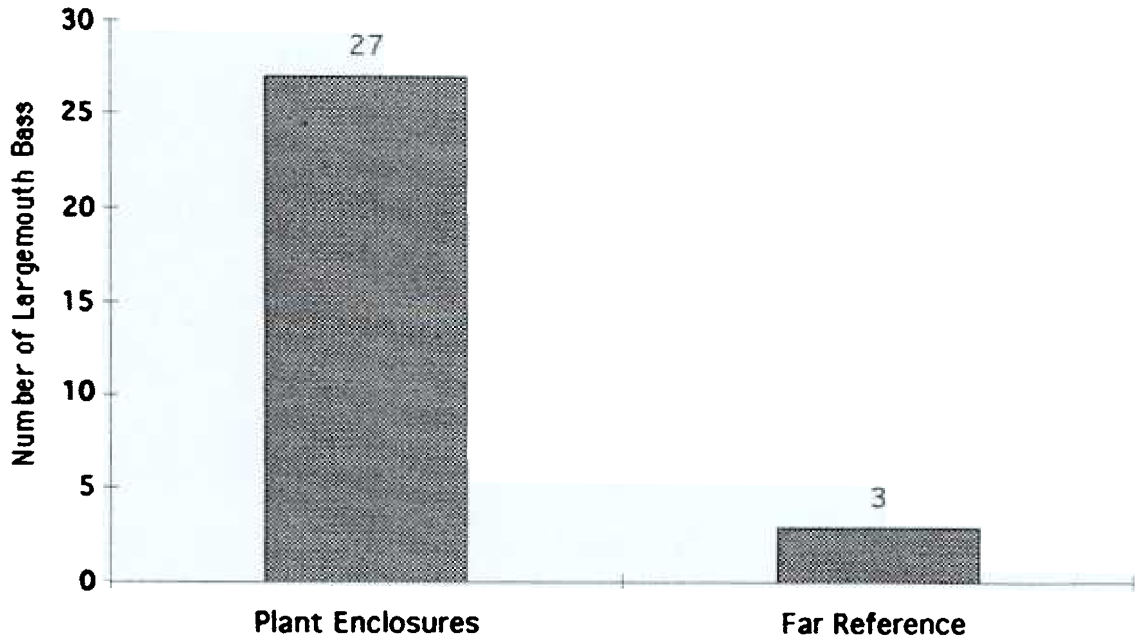


Figure 3-9. Total catch of juvenile largemouth bass in plant enclosures and far reference sites in Onondaga Lake, 1993.

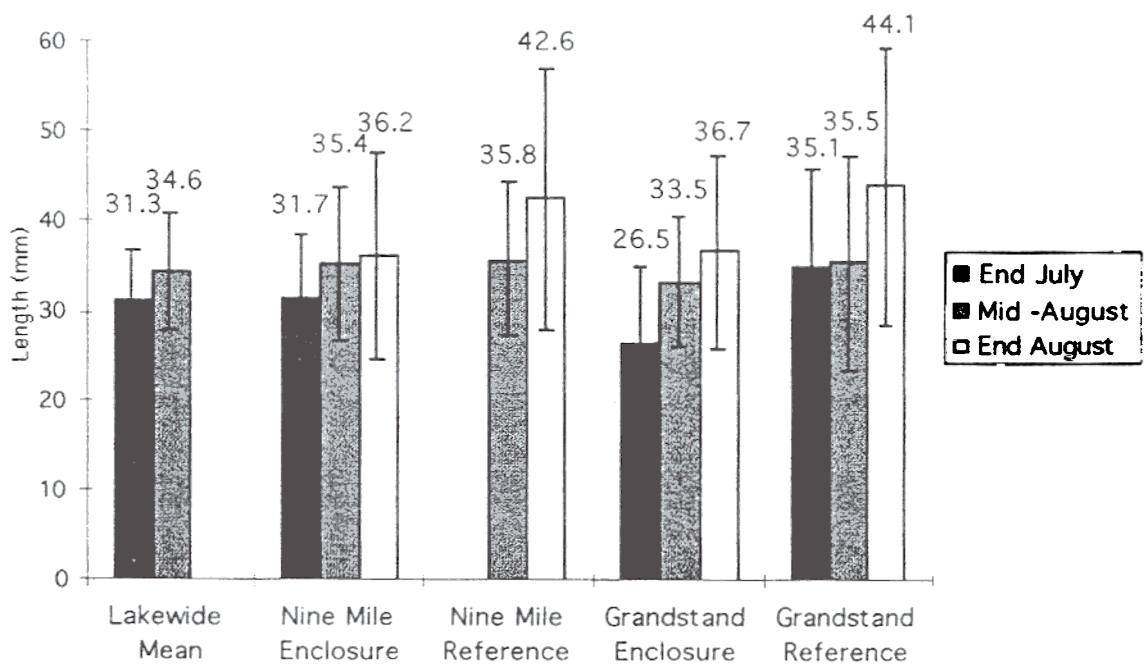


Figure 3-10. Mean lengths of sunfish, with 95% CI, in plant enclosures, reference sites and within Onondaga Lake, 1993.

4.0 CONCLUSIONS

4.1 Reproduction and Recruitment

1 Few fish species that are present in Onondaga Lake as adults, and that typically reproduce in lakes, appear to successfully reproduce within the lake.

2. Annual reproductive success in Onondaga Lake appears to be variable, as shown by the apparent lack of significant reproduction in 1992.

3. Most young-of-year fish seem to be produced in the north basin, where the majority of nests have been observed.

4. Low densities of nests and young-of-year in the south basin are most likely due to habitat degradation.

5. Growth rates of young-of-year largemouth bass appear to exceed the New York State average. This may be due to lack of competition, early conversion to a piscivorous diet, and/or abundant food resources.

6. The three-pass reduction technique using bag seines in the littoral zone appears to be a viable method of estimating population sizes of some species of young-of-year and yearling fishes. Pelagic species such as white perch and gizzard shad are probably not good candidates for estimation by this method since a significant proportion of the population may not be accessible to the sampling technique.

7. Recruitment of largemouth bass may currently be limited to a maximum of about 10,000 yearlings regardless of young-of-year abundances. At this level of recruitment Onondaga Lake will continue to exhibit lower than average densities of adults.

Water Quality Impacts

1 Onondaga Lake contains many contaminants that are known to cause reproductive abnormalities in fish. Insufficient data exist to conduct a comprehensive statistical analysis of the possible impacts of water quality on fish reproduction in Onondaga Lake.

Littoral Zone Manipulation

1. Littoral zone enhancement structures increased nesting activity of sunfish and largemouth bass. Success rates of nests and survivorship of eggs and larvae within enhancement areas are not known.

2. Littoral zone enhancement in the form of complex structure increased densities of young-of-year fish although no increase in growth rates was evident.

3. Based on a model simulation, large scale littoral zone manipulation appears to increase recruitment and adult densities of largemouth bass.

4. Littoral zone manipulation and natural recruitment will need to produce approximately 50,000 yearling largemouth bass annually to produce typical densities of adults for New York State (16/ha). However, the total area needed to achieve these densities will depend on utilization, nest success, and young-of-year survivorship in future manipulation sites.

5.0 Recommendations

1. An annual program to monitor fish reproduction should be established. This program should entail monitoring of the distribution and abundance of nests around the entire lake as well as the community structure of young-of-year. Because recruitment of individual species can be influenced by the size of the adult stock, adult populations should also be monitored as part of this program.

2. Data for significant water quality variables (all metals, ammonia, pH, temperature, dissolved oxygen) should be collected at a single depth of no greater than 3 m from April to July in addition to epilimnetic volume-averaged samples that have been historically collected. Aluminum concentrations should added to the list of variables sampled for at least one full sample year.

3. Spatial and temporal water quality and habitat data should be taken along with young-of-year fish sampling at least twice during the summer (late July to mid-August, when young-of-year abundance is greatest). This will require that samples be collected at eight sites in the littoral zone during the same week that young-of-year sampling occurs.

4. An annual or biennial program to quantitatively monitor macrophyte distribution and diversity should be established.

5. A toxicological study should be undertaken to compare the effects of contaminants (especially ammonia and mercury) on survival, growth and development of young-of-year of fishes of several species (especially sunfish, yellow perch and largemouth bass). Water from Onondaga Lake could be compared to that in Oneida Lake and/or Otisco Lakes, which might prove to be appropriate controls. This study would be linked with an ecological component to model potential changes in fish recruitment in response to annual fluctuations in contaminants.

6. Two full-scale permanent littoral zone manipulation sites should be constructed in Onondaga Lake. Both sites should be constructed in waters 1 to 2 m deep to allow largemouth and potentially smallmouth bass to utilize the structures. The first site should be in an area that currently supports moderate nesting and young-of-year activity. The second should be constructed in an area with limited nesting and young-of-year activity. Both sites should be carefully monitored to determine densities (#/unit area) of bass that utilize the sites, nest success rates, and survivorship of eggs and larvae. The results of manipulation site monitoring should be used to determine total number of sites needed or total area to be manipulated.

LITERATURE CITED

Arrigo, M. A. and N. H. Ringler. 1994. Using aquatic macrophyte cover and removal models to estimate yearling recruitment. Unpublished manuscript SUNY ESF Graduate Fish Ecology Course.

Aquatic Toxicology Laboratory. 1990. The acute toxicity of Onondaga County's sewage plant effluent to the fathead minnow, Pimephales promelas. Prepared for County of Onondaga Department of Drainage and Sanitation.

Auer et al. 1982. Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. Special Publication 82-3, Great Lakes Research Division University of Michigan. 743 p.

Auer N. A., and M. T. Auer. 1987. Field evaluation of barriers to walleye egg and larvae survival in the Lower Fox River, Wisconsin. American Fisheries Society Symposium 2: 93-101.

Beauchamp, W. W. 1908. Past and present of Syracuse and Onondaga County, New York. S.J. Clarke Publ. Co., New York.

Bergerhouse, D. L. 1992. Lethal effects of elevated pH and ammonia on early life stages of walleye. N. Amer. J. Fish. Mngt. 12: 356-366.

Bettoli, P. W., M. J. Maceina, R. L. Noble, and R. K. Betsill. 1992. Piscivory in largemouth bass as a function of aquatic vegetation abundance. N.A. Amer. J. Fish. Mngt. 12: 509-516.

Birge, W. J., R. D. Hoyt, J. A. Black, M. D. Kercher, and W. A. Robinson. 1993. Effects of chemical stresses on Behavior of larval and juvenile fishes and amphibians. American Fisheries Society Symposium 14:55-65.

Carlander, K. D. 1977. *Handbook of Freshwater Fishery Biology,* Vol 2. The Iowa State University Press, Ames. 431 pp.

Chiotti, T. L. 1981. *Onondaga Lake Survey Report, 1980 and 1981.* New York State Department of Environmental Conservation. Albany, New York. 14pp.

Doherty, P, and T. Fowler. 1994. An empirical test of recruitment limitation in a coral reef fish. Science 263: 935-939.

Donaldson, E. M. 1990. Reproductive indices as measures of the effects of environmental stressors in fish. American Fisheries Society Symposium 8:109-122.

Edwards, E. A., G. Gebhart, and O. E. Maughn. 1983. Habitat suitability information:" Smallmouth bass. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.36. 47 pp.

Effler , S. W. and R.D. Henigan. 1996. Onondaga Lake: legacy of pollution. Lakes and Reserv. Manage. 12(1):1-13.

Fox, W. S. 1930. The literature of Salmo salar in Lake Ontario and tributary streams. Transactions of the Royal Society of Canada, Section II, Series III. pp. 45-55.

Gandino , C. J. 1996. Community structure and population characteristics of fishes in a recovering New York lake. Masters Thesis. SUNY College of Environmental Science and Forestry, Syracuse NY. 108 pp.

Greeley, J. R. 1928. Fishes of the Oswego Watershed. pp84-248 In: A biological survey of the Oswego River system. Supplement to Seventeenth Annual Report, State of New York Conservation Department. Albany, NY.

Gutreuter, S. J., and R. O. Anderson. 1985. Importance of body size to the recruitment process in largemouth bass populations. Trans. Amer. Fish. Soc. 114: 317-327.

Hall, L. W., Jr., S. E. Finger, and M. C. Ziegenfuss. 1993. A review of in situ and on-site stripped bass contaminant and water-quality studies in Maryland waters of the Chesapeake Bay Watershed. American Fisheries Society Symposium. 14: 3-15.

Hanson, M. A., and M. G. Butler. 1990. Early responses of plankton and turbidity to biomanipulation in a shallow prairie pond. Hydrobiologia 200/201: 317-327.

Hoff, M.H. 1991. Effects of increased nesting cover on nesting and reproduction of smallmouth bass in northern Wisconsin lakes. First International Smallmouth Bass Symposium. pp. 39-43.

Hyatt, K. D. and N. H. Ringler. 1989. Role of nest raiding and egg predation in regulating population density of threespine sticklebacks (Gasterosteus aculeatus) in a coastal British Columbia lake. Can. J. Fish. Aquat. Sci 46: 372-383.

Kohler, C. C., R. J. Sheehan, and J. J. Sweatman. 1993. Largemouth bass hatching success and first-winter survival in two Illinois reservoirs. N. A. J. Fish. Mngt. 13:125-133.

Kwak, T.J., 1992. Modular microcomputer software to estimate fish population parameters, production rates and associated variance. Ecology of Freshwater Fish (1): 73-75.

Lewis, S. D. and W. M. Lewis. 1971. The effect of zinc and copper on the osmolality of blood serum of the channel catfish and golden shiner. Trans. Amer. Fish. Soc. 101(4): 639-643.

Little, E. E., J. F. Fairchild, and A. J. DeLonay. 1993. Behavioral methods for assessing impacts of contaminants on early life history stages of fishes. American Fisheries Society Symposium. 14:67-76.

Madsen, J. D., R. M. Smart, J. W. Sutherland, J. A. Bloomfield, L. W. Eichler, and C. W. Boylen. 1993. Onondaga Lake, New York: Distribution and abundance of aquatic vegetation related to the fertility of oncolite sediments. M. C. Landin editor In: Wetlands:

proceedings of the 13th annual conferance of the society of wetland scientists, New Orleans, LA,.

Madsen, J.D., J.A.Bloomfield, J.W. Sutherland, L.W. Eichler and C.B. Boylen. 1996. The aquatic macrophyte community of Onondaga Lake: Field survey and plant bioassays of lake sediments. Lake and Reserv. Manage. 12(1): 73-79.

Madsen, J.D., J.W. Sutherland, J.A.Bloomfield, L.W. Eichler and C.B. Boylen, N.H. Ringler, D.L. Smith, C.A.Siegfried, and M.A. Arrigo. 1996 Onondaga Lake littoral zone manipulation to improve fish habitat. Final report to the Onondaga Lake Management Conference. Syracuse, NY. 53pp.

Mraz, D. 1964. Observations on large and smallmouth bass nesting and early life history. Wisconsin Conservation Department, Research Report 11, Madison, Wisconsin.

Northeast Division of the American Fisheries Society. 1993. Biological characteristics of black bass populations in northeastern United States and southeratern Canada. Warmwater Workshop: Managing Black Bass in Northern Waters. Alexandria Bay, NY. October 5-6. 1993

Northeast Division American Fisheries Society Warmwater Workshop: Managing black bass in northern waters. October 5-6, 1993. Alexandria Bay, NY. 21 pp.

Pierce, C. L., J. B. Rasmussen, and W. C. Leggett. 1990. Sampling littoral fish with a seine: corrections for variable capture efficiency. Can. J. Fish. Aquat. Sci. 47:1004-1010.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Canada No. 191. 382 p.

Ringler, N. H., C. J. Gandino, P. Hirethota, R. Danehy, P. Tango, M. A. Arrigo. C. Morgan, M. Murphy, R. J. Sloan, S. W. Effler. 1994. Fish communities and habitat in Onondaga Lake, adjoining portions of the Seneca River, and lake tributaries. Chapter 6 in S. W. Effler (ed.) Onondaga Lake: lessons in limnology and engineering analysis. Springer-Verlag, New York, NY.

Robinette, H. R. 1976. Effect of selected sublethal levels of ammonia on the growth of channel catfish (Ictaluraus punctatus). Prog. Fish Cult. 38(1): 26-29.

Sagalkin, N. 1992. A survey of the reproductive activity of pumpkinseed (Lepomis gibbosus) and bluegill (Lepomis macrochirus)sunfish within Onondaga Lake. Unpublished manuscript, SUNY College of Environmental Science and Forestry.

Sheehan, R. T. and W. M. Lewis. 1986. Influence of pH and ammonia salts on ammonia toxicity and water balance in young channel catfish. Trans. Amer. Fish. Soc. 115:891-899.

Shirley, K. E., and A. K. Andrews. 1977. Growth, production, and mortality of largemouth bass during the first year of life in Lake Carl Blackwell, Oklahoma. Trans. Am. Fish. Soc. 106(6): 590-595.

Sinnott, T. J. and N. H. Ringler. 1987. Population biology of the brown bullhead (Ictalurus nebulosus Lesueur). J. Freshwater Ecology 4(2): 225-234.

Smith, C.L. 1985. The inland fishes of New York State. New York State Department of Environmental Conservation. Albany, New York. 522 pp.

Stone, U. B. , N. Pasko and A.C. Pettey. 1946. Onondaga Lake Investigation. Unpubl. report, Western District New York State Conservation Department. 3pp. and 4 tables.

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982. Habitat suitability index models: Largemouth bass. U.S. Dept. Int. Fish. Wildl. Serv. FWS/OBS-82/10.16. 32 pp.

Suter, G.W.II., and J.B. Mabrey. 1994. Toxicological benchmarks for screening potential contaminants of concern for effects on

Aquatic Biota: 1994 revision. Oak Ridge National Laboratory U.S Department of Energy contract DE-AC05-84OR21400.

Tango, P.J. and N. H. Ringler. 1996. The role of pollution and external refugia in structuring the Onondaga Lake fish community. Lake and Reserv. Manage. 12(1): 81-90.

Timmons, T. J. and W. L. Shelton. 1981. Early growth and mortality of largemouth bass in West Point Reservoir, Alabama-Georgia. Trans. Amer. Fish. Soc. 110: 489-494.

Thurston, R. V. and R. C. Russo. 1981. Ammonia toxicity to fishes. Effect of pH on the toxicity of the un-ionized ammonia species. Am. Chem. Soc. 15(7): 837-840.

Tomasso, J. R., C. A. Goudie, B. A. Simco, and K. B. Davis. 1980. Effects of environmental pH and calcium on ammonia toxicity in channel catfish. Trans. Amer. Fish. Soc. 109: 229-234.

Webster, D. A. 1982. Early history of Atlantic salmon in New York. New York Fish and Game J. 29(1): 26-44.

Van Donk, E., R.D. Gulati and M.P. Grimm. 1990. Restoration by biomanipulation in a small hypertrophic lake:first-year results. Hydrobiologia 191: 285-295

VITA

Name: Mark Anthony Arrigo

Date and Place of Birth: March 3,1969 Syracuse, New York

Education

Name and Location	Dates	Degree
Baker High School	1984-1988	
SUNY Morrisville	1988-1990	
SUNY College of Environmental Science and Forestry	990-1993	
SUNY College of Environmental Science and Forestry	994-1998	

Employment

Employer:	Dates:	Job Title:
SUNY CESF	1990-1995	Research Technician
PTI Environmental Services	1992-1993	Research Technician
HydroQual Inc.	1997-Present	Research Scientist